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Act for [illegible] 41

[illegible] made by this ſtate, [illegible]

[illegible] perſons in poſſeſſion of certain [illegible] to have [illegible] privileges with reſpect to [illegible] 500 and 5[illegible]

Time limited for the [illegible] the patents heretofore [illegible] extended, 591

Time in which actions [illegible] be commenced for the recovery of certain lands in the military tract, extended, 611

Certain lands may [illegible] to the people of this ſtate, ib.

LAND OFFICE, COMMISSIONERS OF

To [illegible] in the Oneida, Onondaga, Cayuga and [illegible] Creek reſervations, 33[illegible]

To ſell the houſe in [illegible] ſtreet in the city of Albany, [illegible]

To direct lots in the vicinity of Black Rock to be ſold, [illegible]

To [illegible] ſurveyor-general's plan of Black Rock, ib.

LAWS.

State printer to have them bound in boards, 32

LEWIS COUNTY.

Terms of the [illegible] of common pleas and general ſeſſions of the peace [illegible] when and how long to be held, 551

Certain [illegible] relating to [illegible] in Jefferſon and Lewis [illegible] ib.

Accounts of county [illegible] to [illegible] court houſes how audited and paid, 636

[illegible]

M[illegible]

[illegible] incorporat[illegible]

[illegible] relating to

ames [illegible]

Jaſon and [illegible]

[illegible] of paym[illegible]

[illegible]

Comptroller [illegible]

[illegible]

[illegible] of mortg[illegible]

purſuance

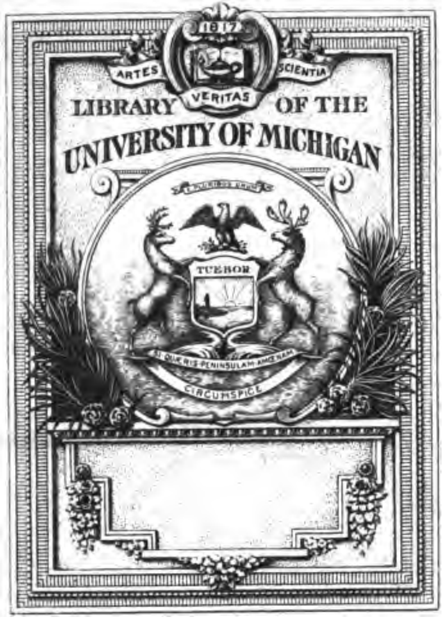
Heretofore ma[illegible] valid,

[illegible]

[illegible] for [illegible]

Time for comp[illegible]

[illegible]



H. L. Smith

Troy Seminary. 182

Chemical Instructor:

PRESENTING

A FAMILIAR METHOD OF TEACHING

THE

CHEMICAL PRINCIPLES

AND

OPERATIONS

OF THE MOST PRACTICAL UTILITY

TO FARMERS, MECHANICS, HOUSEKEEPERS AND PHY-
SICIANS; AND MOST INTERESTING TO
CLERGYMEN AND LAWYERS.

INTENDED FOR ACADEMIES AND FOR THE POPULAR CLASS-ROOM.

BY AMOS EATON, A. M.

Attorney and Counsellor at Law; Professor of Chemistry and Botany in the Vermont
Medical Institution, which is connected with Middlebury College, and
Lecturer in the Troy Lyceum; Member of the New-York Lyceum, of the American Geological Society, &c. &c.

ALBANY:
PRINTED AND PUBLISHED BY WEBSTERS AND SKINNERS.
1822.

NORTHERN DISTRICT OF NEW-YORK, ss.

BE IT REMEMBERED, That on the twentieth day of February, in the forty-sixth year of the Independence of the United States of America, WEBSTERS & SKINNERS, of the said district, have deposited in this office the title of a book, the right whereof they claim as proprietors, in the words following, to wit:

"Chemical Instructor: presenting a familiar method of teaching the Chemical Principles and Operations of the most practical utility to Farmers, Mechanics Housekeepers and Physicians; and most interesting to Clergymen and Lawyers. Intended for Academies and for the Popular Class-Room. By Amos Eaton, A. M. Attorney and Counsellor at Law; Professor of Chemistry and Botany in the Vermont Medical Institution, which is connected with Middlebury College, and Lecturer in the Troy Lyceum; Member of the New-York Lyceum, of the American Geological Society, &c. &c."

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RICHARD R. LANSING,
Clerk of the N. District of New-York.

TO

DR. T. ROMEYN BECK,

PRINCIPAL OF THE ALBANY ACADEMY—AND

MRS. EMMA WILLARD,

PRECEPTRESS OF THE TROY FEMALE ACADEMY.

This little treatise being chiefly intended for all respectable public schools, excepting colleges, and you having been the first, in the interior of the Northern States, to introduce experimental chemistry into such schools; it appeared to be your right to approve or condemn.

With the hope, that I have not mistaken your views in relation to the method of communicating useful knowledge on a subject of so much practical utility,

I subscribe myself,

Your obedient humble servant,

AMOS EATON.

Troy, Feb 5th, 1822.

PREFACE.

AFTER the appearance of so many excellent treatises on the science of chemistry, of all sizes and all forms, it will be very natural to ask; what useful purpose can the author of another elementary work have in view? To this I answer, that I have undertaken to present the science in a manner, which shall render it accessible to all academies, and to all other public schools, when competent teachers are employed; also to popular assemblies, where lectures are given. I have even endeavored to bring down the sublime science of chemistry within the reach of the laboring agriculturalist, the industrious mechanic and the frugal housekeeper. But in doing this, I hope I have not degraded the science by low or vulgar descriptions; though I have every where aimed at a familiarity in manner, which must necessarily sink below that style which is always desirable.

I have not intentionally omitted any principle, which applies to the common purposes of life; or which explains phenomena interesting to the student, who is not over curious. Those discusons and experiments, which are directed to minute points, as how many states of oxydation Cereum or Tellurium is capable of, the possible number of Chlorates and Iodates, and other possible combinations, I have totally omitted. But I have endeavored to elucidate and explain the application of every *practical* principle of the science.

I have not directed the instructor to one experiment, which I have not myself repeated. I have not copied the description of an experiment from any author whatever. But I have written out the description of every experiment from my own recollection of the manner in which I have performed it, excepting a few experiments in galvanism, and two or three others, which I have described, but not recommended; and those I wrote from my recollection of the manner in which I have seen Prof. Silliman and others perform them. I did not adopt this method of writing descriptions from recollection, because I expected in this way to arrive at more accuracy or more perspicuity. But I believe, and I hope my readers will agree with me in opinion, that I have made my descriptions more accessible to juvenile minds, by writing as I would talk to a class of young persons, whom I wished to instruct, than could have been done by copying from the accurate and the elegant.

I have selected those experiments which can be performed with least expense, and which are most unequivocal in their application. I have also given my directions with a particular view to the materials which will be within the reach of the instructor. Having given seventeen experimental courses before mixed audiences of learned and unlearned, in small villages as well as in cities; I have learned from experience to subject myself to various caprices and to dispense with many conveniences. And the reader is requested to ascribe whatever he finds in this little treatise of a peculiar character, savoring of affected singularity, to this cause.

This school book, as far as it goes, may guide the infant steps of him, who calculates to become a giant in chemistry. And this course of experiments will enable the intelligent student to read any work on the subject understandingly, however elaborate. It may be used as a stepping-stone to such works as M'Neven's Brande, Silliman's Henry, Gorham's Chemistry; and finally to the great works of Murray and Thomson.

INTRODUCTION.

IN WHICH THE NECESSARY APPARATUS IS DESCRIBED, AND DIRECTIONS GIVEN FOR EXERCISING STUDENTS AT THE CISTERN AND MERCURIAL TROUGH.

After the instructor has exhibited the elementary substances, and before he enters upon his course of experiments, he ought to exhibit the most important part of his apparatus, and cause his students to perform the most common pneumatic operations of the cistern and of the mercurial trough. He may conveniently do this by bringing in, by appointment, half a dozen at a time; and by making use of atmospheric air as a substitute for other gases. Let each student's own hands be applied, by turns, to these operations. Half an hour will be sufficient for six students to become sufficiently acquainted with the pneumatic operations to understand the experiments, afterwards to be performed, by the instructor. The water of the cistern should be previously warmed, and all acids and alkalies washed from the cistern, tables, &c. to avoid injuring the health of the class by exposing their hands and arms to cold water, or their clothes by the acids and alkalies.

APPARATUS.

Pneumatic cistern. For an economical course of instruction, such as that proposed in the following work, a wooden box, three feet long, eighteen inches deep and eighteen inches wide, will be sufficient. It is made of pine plank, so arranged that the grains of the wood all run in the same direction; so that all the pieces, constituting the cistern, may swell and shrink uniformly. Consequently, in the end pieces the grains are vertical.

Grooves are cut in the side pieces to let in the bottom and the end pieces. There is not a nail nor a pin used for holding it together. It is wholly secured by iron rods with nuts and screws, resembling sleigh rods; and these are confined to the two side pieces. Three rods at each end and four under the bottom are sufficient. These may be loosened and tightened, by turning the nuts, as the planks swell and shrink. A lid is attached to one end of the cistern by strong iron hinges. This is very useful for covering up the cistern to prevent its freezing in cold weather, for the convenience of transportation, and to serve for a table when open.

The inside of the cistern is divided into three equal parts, by inch square posts, screwed to the side pieces within, and by beams an inch and a half in depth and an inch thick resting upon, and screwed to the upper ends of the posts. The upper sides of the beams are four inches lower than the top of the cistern. The middle division is the well; across which, with its ends supported on the beams, is the moveable shelf. This is three inches wide and two inches thick, having two inverted tunnels wrought in its under side, terminating upwards in small holes perforating the shelf. One of these holes in about three fourths of an inch in diameter, which is generally used; the other is a quarter of an inch in diameter, which is used for filling vials with gases. Shoulders are cut at each end of the shelf, letting it down so that it is but half an inch higher than the top of the beams; and half buttons are screwed under side, so near the ends as to be outside of the tunnels, in order to button the shelf to the beams to prevent their rising up.

The division on one side of the well is filled with a wooden gas-holder; which consists of an inverted box. The bottom of the box being upwards, it serves for a shelf; and the box is made of such a depth, that it forms a shelf on a level with the moveable shelf. A semi-circular hole is cut in the side of the gas-holder next to the well and adjoining the bottom of the cistern, for the convenience of pouring under gasses with the bell-glasses.

The division on the other side of the well contains two tin gas-holders, with rings to raise and lower them by. These are of a suitable depth for forming shelves on a level with the moveable shelf also. But they have no hole or opening on their sides, excepting a slit or kind of scollop half an inch wide; for they are raised up by their rings and suspended by strong wire hooks, which are attached to the cross bar, when gases are introduced into them.

Each gas-holder has a half-inch hole and a quarter-inch hole, for the admission of a large and a small stop-cock, tube or stopper. Half inch tin cylinders are soldered to the upper sides of the holes in the tin gas-holders, to steady the stop-cocks. And that part of them, being used for shelves, ought to be made of double tin sheets to stiffen them.

Two narrow slips of board are screwed on the outside of the cistern, in a vertical position, opposite to each other, against the centre of the division containing the tin gas-holder, which are connected at the top by a cross-bar. They are of such a length, as to elevate the cross-bar about twenty inches above the top of the cistern. If the cistern is to be transported from place to place, the posts must be supported by a piece of sheet iron, of a staple-like form, screwed on the outside of the cistern, so that they may be conveniently taken off.

A forge and furnace. Let a sheet iron stove be made, 22 inches long, 16 inches wide and 16 inches high. Let the corners be as nearly square as the sheet iron can be conveniently wrought. Let a hole be made in one end about an inch in diameter, 3 inches above the bottom, for the admission of a bellows pipe. Place the neck for the stove pipe on the top, very near the opposite end. Cut an opening for a door in the middle of one side of the stove, nearly of a semi-circular form with the strait side down, 3 inches above the bottom. Let its strait side be 12 inches, and the height 8 inches. Let the piece so cut out be used for a door or lid, by shoving it up one inch, and supporting it at that height by 2 iron pins near the top of the opening on the outside and two corresponding holes in the upper edge of the lid to suspend it by. Cut a hole one inch and a half in diameter, opposite to the centre of the base of the door, 2 inches above the bottom of the stove. A suitable length of pipe for conducting off the smoke under the mantle piece of a chimney or out at a window, finishes the iron part of the forge. A dripping pan, with a 3 inch brim, as large as can be put into the door, will be wanted for a sand bath. To use this apparatus, make a strong bench, about 3 feet high, and a few inches wider and longer than the stove, and set it about 8 feet back of the cistern. Let it be so situated that every auditor can see an experiment at the nose of the bellows. Cover the bench with brick, and set the stove upon them. Set up a row of brick edgwise around the inside of the stove. Bore a hole through two brick for the bellows pipe to go through. Then lay a floor of one thickness of brick inside of the stove.

When a forge is wanted, put in the coal, leaving the door or lid off, and proceed as with other forges. When a sand bath is wanted, set in the dripping pan half filled with sand, supported on another lining of brick, with coal filled in. The heat under the pan may be regulated by the bellows; or the lid may be put up and a brick left off in front, when the inch opening under lid will operate as an air furnace. It may be used as an air furnace for any other purposes in the same way. But I always prefer regulating the heat by the bellows. I have then the perfect command of the heat, and can contract, enlarge or otherwise direct it, by the aid of loose brick and by leading the coal with a poker. The sheet iron sides of the stove may be as easily defended with the loose brick, as if set in morter. I am careful to keep a quantity of square-edged brick, squared on a grindstone, of equal dimensions.

A Bellows. A bellows two feet and a half long is sufficient for any experiments. Two upright strips of board and a cross-bar make a sufficient frame for hanging it.

Tongs. One light pair of tongs, with the rivet near the bows, like taylors' shears; and one pair fitted both to hold a crucible and to pinch a small thing as a nails are sufficient.

Crucibles. One large lead pot, having a top large enough to take in a pint retort; and two or three nests of common crucibles.

Gun-barrels. Two gun-barrels, perfectly stopped at the brich, and air tight, will be wanted; for that which is kept for oxygen must not be used for carburetted hydrogen nor for any other purpose, but collecting oxygen.

Gas-tubes. Two leaden tubes, drawn down to about half the size of leaden aqueduct tubes, long enough to reach from a gun-barrel set in the forge, to half across the cistern. A few tin and glass tubes will be wanted of various sizes.

Stop-cocks. About half a dozen good stop-cocks, will be necessary. Small brass cocks at the hardware store will do, if no better can be had, by filing off the crooked part.

Flexible tubes. These may be made of good calf-skin. Such tubes will not hold the gases, unless they are soaked in water three or four hours before they are used; or a shorter time if the water is moderately heated.

Ladle and Spoons. A common iron ladle, which will hold a pint or a little less. A common iron table spoon, a tea-spoon, and silver mustard spoon.

Glass ware. 6 Plain pint retorts, 3 tubulated half pint retorts with long necks, 3 tubulated half pint retorts with short necks, 2 half gallon bell-glasses, 2 quart bell-glasses, 2 tubulated quart bell-glasses, 6 assay glasses without feet or noses, sometimes called glass-cylinders, 2 boltheads or mattrasses with 18 inch necks, 1 air thermometer, made like a bolthead only more slender and delicate, a dozen test glasses.

Borrowed glass ware, crockery, &c. Any liberal crockery merchant and druggist will lend the following articles, on condition they are paid for or returned clean and sound. 2 dozen plain wine glasses, 6 quart and 6 pint tumblers, 6 large and 6 small white earthen plates, 2 plain pitchers, 6 quart and 6 pint earthen bowls, 2 large wash bowls, 2 small specie bottles, 2 large specie bottles, 2 decanters, an iron and a wedgewood mortar.

Mercurial trough. Get a mercurial trough cut in a block of marble, about 9 inches long and 6 wide. Let it be cut 3 inches deep, 6 inches long, and so narrow as to hold 12 lb. of mercury, and leave an inch unfilled. A deep groove, for laying down a vial, in the centre of the bottom. Any druggist will lend the mercury, if the deficiency in weight be paid for.

Reflectors. Get a pair of tin concave reflectors, about 10 inches in diameter. Also a ball of iron with an eye to hang it by, for using with the reflectors.

Scales. An accurate pair of scales with grain weights.

Florence flasks and large vials. About a dozen of each.

Bags. About a dozen bags, large and small, made as follows. Procure the smoothest and strongest dry bladders from the butchers. Rub them between the hands until they are soft; picking off all the fat, fibres, &c. attached to them. Cut off the rough part of the necks, and put into each a tin tube 3 inches long and of a diameter just sufficient to receive a stop-cock. Then procure a cork to fit each accurately. Into these bags gases may be transferred by compressing them closely and applying their mouths to a stop-cock of a gas-holder. A label of the name of the gas may be tied to the tin neck, and th gas laid aside for future use. Oxygen in particular, more or less of which is always wanted, may be made up in large quantities and kept in this way through a whole course. One slender bent tin tube may be made and attached to a stop-cock to fit all the necks. When the gas is to be used the cork is taken out and the tube put in with the mouth under water. Then by compressing the bag the gas may be transferred to whatever place it may be wanted for use.

Kettle. A sheet iron kettle, holding about 3 quarts with a handle on one side 18 inches long, and a pouring nose on another side.

Dripping pan. An extra dripping pan, besides that used for a sand bath, about 12 inches square for holding coals, and for setting the lead pot in. This may be set on a couple of bricks laid on a table or bench, when coals are put in the pan, or when the lead pot contains coals and is set in it.

Fender plates. A square plate, whose breadth is about equal to the length of the lead pot, is necessary for defending the side of the cistern from the heat of the lead pot or from the coals on the dripping pan, when they are used near the side of the cistern for heating retorts, &c. A sheet of tin with slips cut and bent so as to make it stand on one edge upon a table, is wanted also.

Etching box. A box of tin, lead or copper is better, two inches square and two inches high, open and perfectly even on the top. It should be set in a hole in the centre of a tin plate, so that cold water may be poured on a piece of glass laid over its top, without wetting the coals on which the box stands.

Fire Syringe. A syringe of lead, pewter, or other metal, six inches long, and closed at the end.

Hammers, a block of iron for an *anvil*, *wire* of various sizes, *gallipots*, *tobacco pipes*, *pinchers*, *cork screws*, and numerous other small articles will be wanted; which will occur to any instructor without particular directions.

EXERCISES,

AT THE CISTERN AND MERCURIAL TROUGH.

The cistern is set firmly upon short cross benches, elevated sufficiently to bring the top of it to the instructor's elbows. It is filled quite full of water. A tub stands under it with one edge projecting a few inches, directly under a large brass cock, which is fitted in, level with the inside bottom of the cistern. A long horizontal hole or slit is cut against the centre of the well, half an inch below the top, which is four or five inches long and half an inch thick. A stopper is fitted to this, which may be pulled out to let the water run through it into the tub, when the experiments are of that kind, which may cause the cistern to run over.

1. *Let each of the students fill the bell-glasses with water and set them on the shelves.* Hold a bell-glass, tumbler, cylinder, or specie bottle, in a horizontal position

over the well. Sink it in this position until it is almost full, lower the closed end until all the air passes out; then turn the closed end upwards and raise it carefully, pressing it against the shelf until it is high enough to slide on the shelf.

2. *Let each student transfer air from one bell-glass to another.*

In this operation let the air be carefully poured up under water, into a glass previously filled with water, so that no bubbles shall escape.

3. *Let each student pour air into the wooden gas-holder, through the semi-circular hole.*

In performing this operation, slide the vessel down against the gas-holder, keeping it in a vertical position until it reaches the bottom of the cistern. Then incline it towards the horizontal position, and at the same time crowd it gradually into the gas-holder.

4. *Let each student pass a current of air from a gas-holder by way of a stop-cock through a tin tube.*

A stop cock is fitted into one of the holes of a gas-holder (the other hole being stopped with a peg,) and the gas holder is afterwards filled with air. If it is the wooden one, the air is poured under as before mentioned, or blow it under through a tube. If it is one of the tin gas-holders, stop it close and draw it up by the handle, it being full of water, and apply the ring to a hook which is attached to the cross-bar. Now blow the air under through a tube, or pour it in from a bell-glass. The gas-holder being filled, press it down to the bottom of the cistern, and stay it there by applying the moveable brace, which is morticed into the cross-bar. Wring a tin tube on to the stop-cock, and now turn the stop. A strong current will be forced out by the pressure of the water of the cistern into the gas-holder below.

5. *Let each student pass a current of air from a gas-holder through a flexible tube and tobacco-pipe, and make soap bubbles.*

Perform this operation as the last, with the following additions. Put the flexible tube upon the end of the stop-cock and tighten it by winding waxed threads around it. Fasten it to the tobacco pipe in the same way. Set a bowl of soap suds on a table within reach of the flexible tube. Dip the pipe bowl into the suds, turn the stop, and a current of air will be pressed out and inflate the bubbles.

6. *Let each student fill a small glass cylinder, invert it and set it on the shelf of the mercurial trough.*

This operation is performed as directed with water. But requires that the glass cylinder be grasped firmly and held steadily.

7. *Let each student transfer air from one cylinder to another over mercury.*

This operation is performed like the same over water; but as soon as the vessel is nearly emptied it will be lifted up and overset by the mercury. To obviate this difficulty, moveable straps of tin cross the trough and bend down at each end to fit the outside of the trough. A hole is made through each strap, so as to come over the shelf, rather larger than the largest of the cylinders used in the trough; which is about an inch and a half. On the under side of each strap of tin a tin cylinder is soldered on, to surround the hole, for the purpose of steadying the glass cylinders—these tin cylinders are never so long as to reach the mercury. Slits ought to be cut in their sides, so that the contents of the glass cylinders may be seen. When they are filled with mercury, one of those tins should be set over each; then they may be filled with air conveniently without falling down.

8. *Let each student pass air into a glass-cylinder over mercury from a bag, according to the method necessary when the gas was collected over water, and it is required that the cylinder should be perfectly dry.*

Compress the bag so as to force out all the air. Wring the tin mouth tight upon a stop cock which is fixed into the hole of one of the gas-holders, and tighten it with wet tow if necessary; at the same time let the collapsed bag be held upright to prevent its getting wet. Having put a sufficient quantity of air into the gas-holder, as before directed, now turn the stop, and the water of the cistern will press the air into the bag, until it fills. Disengage the bag from the stop-cock, at the same time slip the thumb over the tin mouth of the bag. All being ready, take off the thumb and instantly wring in a closed stop-cock, which has a slender curved tube attached to it. Press the bag a little in the interval, between removing the thumb and inserting the stop-cock, so as moderately to force out air, in order to be sure that none passes in.

Now take the bag to the mercurial trough, and immerse the end of the tube in the mercury, with the curved tip pointing upwards. Press the bag and force out a little air, sufficient to force out all that was previously in the pipe. Then set a cylinder over the tip of the tube, which was previously filled with mercury. Compress the bag, turn the stop and fill the cylinder full, which will force down the mercury.

9. *Let each student use a retort by passing a common gas into a receiver.*

In performing this experiment, let the students produce either hydrogen or carbonic acid gas in the common way. Let it be received through a funnel hole in the moveable shelf into a bell-glass.

10. *Let each student take the specific gravity of a mineral.*

Weigh a small mineral specimen in the air, suspended from a beam of the scales by a fine silk thread. Then let it hang in a tumbler of water and weigh it there. Now subtract the weight in water from the weight in air, and divide the weight in the air by the difference, and the quotient will be the specific gravity.

CHEMICAL SUBSTANCES,

For a Course of Experiments.

Test for acids and alkalies. Collect in the month of October or November, leaves from the red cabbage. Those of the brightest red are not the best; but those should be selected, which are rather blueish or glaucous. Dry the thinest parts of the leaves by slow heat of a fire or stove. The heat should not be sufficient to dry them in less time than four or five days. When dried sufficiently break them up pretty fine by rubbing them in the hands, and cork them up in dry vials. When wanted for use put about a tea-spoonful into a wine-glass of pure rain or river water, and soak it about an hour. Then press it with a rod and pour off the water into another wine-glass or vial for use. It should never be used after the infusion has been made longer than two or three days.

Procure at the shops, or elsewhere, the following substances:

Sulphuric acid 2 quarts, nitric acid 1 pint, muriatic acid 1 pint, iron filings at the gun smiths 6 pounds, phosphorus 1 ounce, oxymuriate of potash 1 ounce, sulphur 1 roll, sea-coal 6 pounds, hard soap 1 pound, chalk 6 pounds, carbonate of ammonia 1 pound, muriate of ammonia 4 ounces, oxyd of manganese 10 pounds, saltpetre 1 pound, red lead 3 pounds, pearlash 3 pounds, quicklime 6 pounds, fine table salt 2 quarts, white wax 1 cake, borax 2 ounces, fluor spar 2 ounces, carbonate of soda 8 ounces, liquid ammonia 8 ounces, copperas 8 ounces, blue vitrol 2 ounces, alum 2 ounces, white vitrol 1 ounce, magnesia of the shops 2 ounces, epsom salts 2 ounces, sugar of lead 2 ounces, corrosive sublimate 1 ounce, calomel 1 ounce, lunar caustic quarter of an ounce, verdigris 2 ounces, nut galls 2, prussiate of potash quarter of an ounce, spirits of turpentine 1 pint, oxalic acid quarter of an ounce, or it may be obtained in the expressed juice of green wood-sorrel, alcohol 1 pint, ether 1 ounce. A little zinc, tin-foil, bismuth, gold leaf, arsenic, copper filings and lead bar. Also a little gum-arabic, starch, white sugar, sweet oil, rosin, camphor, liquorice in ball, india-rubber, indigo, prussian blue, flowers of benzoin, citric acid, vinegar, glue, isinglass.

It is best to put all these articles into vials or boxes shut closely; and have them all labelled and well arranged.

NOTICES.

All that is intended for the lessons of students in public schools, is printed in italics.

Whenever the instructor wishes farther to illustrate any principle by experiments, he will find enough well described experiments in Silliman's Henry, and a multitude of short descriptions in the little work of Cutbush.

Every instructor ought to have Gorham's Chemistry and M'Neven's Brande. Here full discussions may be found, to aid in the preparation of lectures.

Chemical Instructor.

Whenever a private gentleman, a solitary student, or a public teacher, proposes to acquire or to communicate a knowledge of Chemistry, the elementary constituents of all things with which we have any concern in life, should at the outset be classified, and so arranged that all may be seen and compared at a single view.

There are, in the cabinets of the learned societies, a few rare substances, which are not easily obtained. But any public teacher, who is tolerably assiduous, may enable himself to say to his class, "I " now exhibit before you the elementary constitu- " ents of all material things, with which you have " any acquaintance, excepting a few rare specimens, " which some of you may have seen in the muse- " ums of the curious."

The class should be told, that all the productions of Nature and Art are the result of the various combinations of the substances before them. Consequently, that each individual must become so far acquainted with each of these substances and the chemical powers, before another step is taken in the course, as to associate the idea of one or more of its properties with its name whenever it occurs.

It is not necessary in all cases, that the elementary substances should be separated from their compounds; provided they can be presented to the senses in any manner, so as to enable all the members of the class to fix upon some striking property of each substance, whereby it may be recollected on the mention of its name.

CHEMICAL POWERS AND SIMPLE SUBSTANCES.

In the present state of chemical knowledge, these are estimated at fifty-two in number; all of which are supposed to be simple substances, excepting affinity, which is a property of matter. Some chemists consider caloric, electricity and light, as mere properties of matter also.

They are divided into five classes. 1. *Chemical Powers.* Affinity, Caloric, Electricity, Light. 2. *Acidifying Substances.* Oxygen, Chlorine? Fluorine? Iodine? 3. *Acidifiable Substances.* Hydrogen, Nitrogen, Sulphur, Phosphorus, Carbon, Boron. 4. *Metalloids.* The bases of alkalies and of alkaline earths, Potash, Soda, Lime, Barytes, Strontian, Magnesia—and the bases of earths which are not alkaline, Silex, Alumine, Glycine, Zircon, Yttria. 5. *Metals.* Iron, Manganese, Tin, Zinc—Arsenic, Chrome, Molybden[illegible] Tungsten, Columbium—Copper, Antimony, Bismuth, Cobalt, Titanium, Tellurium, Cerium, Uranium—Gold, Silver, Platina, and its alloys, Palladium, Osmium, Rhodium, Iridium—Mercury, Lead, Nickel.*

These should be exhibited to the class at the commencement of the course; and should be impressed upon the memory by the following remarks and experiments. In public schools the pupils should be frequently questioned upon them, early in the course.

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* Four new simple substances are said to have been recently discovered. Lithium, which is nearly related to Soda; Thormium, said to be connected with Yttria; Selinum, found in sulphur, and resembles tellurium; Cadmium, contained in zinc, and resembles tin. They are all extremely rare, and mostly of a doubtful character.

CLASS I. POWERS.

There are four powers or principles by which all chemical changes are effected ; viz. Affinity, Caloric, Electricity and Light.

Affinity. That kind of attraction, which unites the constituent atoms of material substances.

Illustration. Pour sweet oil into a wine-glass of water. Attempt to mix the oil and water by stirring it. As the oil will continue to remain in globules separate from the water, here is manifestly a want of affinity between the oil and the water. Now put in a little pearlash, and a white liquid soap will be formed of the oil, pearlash and water. This union is effected by the affinity of the pearlash for both the water and the oil.

Caloric. The matter producing heat.

Illustration. By a reference to a stove, candle, &c. The matter of heat exists independent of its effects ; and the sensation perceived by bringing the hand near it, is produced by the motions of this matter, which effect is called heat.

Electricity. A principle, or subtile fluid, which may be excited by friction, so as to produce attraction, repulsion and heat. Lightning is the same fluid most powerfully excited.

Illustration. Rub a clean silk handkerchief, after spreading on it an amalgam of tin, zinc and mercury, upon a clean tube of thick glass; then shew its attractive and repulsive powers by bringing near it the suspended ends of silk threads, down, pith balls, &c.

Light. That principle, or subtile fluid, which *renders material substances manifest to the sense of seeing.*

Illustration. Refer to any object in the room. Here rays of light pass from the candle or window to the object, and are reflected or rebounded to the eye; bringing with them the image of the object, which they impress upon a wide-spread nerve, by which it is communicated to the sensorium, or received by the mind.

* * *

CLASS II. ACIDIFYING SUBSTANCES.

Four substances, supposed to be simple, are said to possess the power of rendering certain other substances acid, and of supporting combustion.—Viz. Oxygen, Chlorine ?* Fluorine ? and Iodine ?

Oxygen. The respirable part of the atmosphere, the only acidifying principle, and th[illegible]ly supporter of combustion, which is applied to the common operations of nature.

Illustration. Having procured some oxygen gas by the process to be described hereafter, exhibit its power of supporting combustion by dipping into it and relighting an extinguished candle by the heat of the wick.

Chlorine. (Oxymuriatic acid.) *A substance*

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[*] The simple nature of chlorine is not demonstrated; for the result of every experiment instituted for the purpose of proving its simple nature can be explained on the principles of Berthollet, Berzelius, Murray and Ure, who call it oxymuriatic acid, or muriatic acid with an additional portion of oxygen. Iodine and fluorine are in a still worse situation. But they may all be retained in this class, without materially embarrassing the science; and it appears to be necessary while the authority of a great name holds this part of chemistry in a kind of vassalage. It is advisable, however, for teachers to conduct their courses in relation to *muriatic acid* and *fluoric acid* upon the principles of Lavoisier, regardless of this parasitic part of chemical nomenclature.

which possesses the power of extinguishing vegetable colours, either in the state of gas or in combination with water. It becomes muriatic acid by being deprived of a portion of oxygen, or else by uniting with and acidifying a portion of hydrogen.

Illustration. Having procured some chlorine in the liquid state, by the red lead process to be described hereafter, obliterate writing and the colours on a piece of calico, by wetting them with it. The writing will disappear in about two minutes, and the colours of the calico will begin to change in five minutes, and some colours will disappear in fifteen minutes.

Fluorine. An essential part of fluoric acid, which dissolves flint and glass. The acid is probably formed by divesting the fluorine of a portion of oxygen; or else by its uniting with, and acidifying, a portion of hydrogen.

Illustration. Put into the etching box a little coarsely pulverized fluor spar. Pour in just sulphuric acid enough to wet it. Set the box on coals in the dripping pan, which may be supported on bricks upon a table. As soon as a vapor appears to arise from the box, cover it with a piece of glass. In about half a minute the glass will be corroded by the fluoric acid gas. Letters may at this time be etched upon the glass, as hereafter described, if the instructor has time to prepare it.

* *Iodine. A substance in the form of dark shining metallic scales, which readily becomes, by the warmth of the hand, a beautiful violet coloured vapour, and it possesses in a small degree, the power of discharging vegetable colours.* It supports the combustion of the basis of potash.

Illustration. This being a substance of no practical use and not yet generally understood, and of a doubtful character, it will be sufficient to show the class a specimen of barilla or kelp from which it is obtained, or even a specimen of sea-weed, from which the kelp is obtained, as containing the iodine if it is a simple substance. Those who wish to analyze this substance are referred to M'Neven's Brande, p. 73, and Gorham's Chemistry, Vol. 1. p. 256. As it resembles chlorine in many of its properties, and is obtained from a substance growing in salt water, it may turn out to be muriatic acid in some state of combination, analagous to oxymuriatic acid, or chlorine.

CLASS III. ACIDIFYABLE SUBSTANCES, NOT METALLIC.

Six simple substances, besides the metals and metalloids, are susceptible of an union with oxygen. Viz. Hydrogen, Nitrogen, Sulphur, Phosphorus, Carbon and Boron.*

Hydrogen. A very inflammable substance when in the state of gas, and the lightest of all gases; though it is the basis of water.

Illustration. Put a gill of water into a junk bottle, and add a table spoon-full of iron filings. Then pour in half a wine-glass of sulphuric acid. As soon as the hydrogen gas rises out of the bottle profusely, light it with a candle. It will explode slightly at first and then burn steadily for a considerable time.

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* The bases of Muriatic and Fluoric acid are removed to class 2d where they are called Chlorine and Fluorine. Future discoveries may bring them back to this class, however.

Nitrogen. That substance which constitutes more than three fourths of the atmosphere, which extinguishes flame, and when breathed alone, destroys life.

Illustration. Fill a soup plate with water. Set in it a small gallipot, which will float on the water. Put in the gallipot a piece of a stick of phosphorus, the fourth of an inch in length. Set the phosphorus on fire with a lighted roll of paper, and the next instant shut over the gallipot a quart bell-glass or quart tumbler. The burning of the phosphorus will consume the oxygen of the air contained in the tumbler, and leave the nitrogen. The water in the plate will rise up and fill the vacuum caused by the loss of the oxygen, while the gallipot will float on its surface. After the white vapour subsides, remove the plate with the tumbler, &c. to a tub or pail of water. In that drop down the plate, draw out the gallipot through the water of the tub, place a piece of well soaked pasteboard over the mouth of the tumbler while under water. Then holding the pasteboard close on the mouth of the tumbler turn it upright and set it on the table. Take off the pasteboard and dip in a burning candle, which will be extinguished. This may be repeated several times, shewing the class that nitrogen extinguishes flame.

Sulphur. A yellow solid inodorous inflammable substance, which becomes a strong-scented suffocating gas on burning.

Illustration. Exhibit a piece of roll brimstone.

Phosphorus. A reddish-yellow substance, of a waxy texture, so highly inflammable as to be inflamed by friction.

Illustration. Lay a shaving of phosphorus on a slip of pine board and rub it with another, when it will take fire and blaze rapidly.

Carbon. A combustible substance, forming the basis of charcoal, and existing pure in the state of the diamond.

Illustration. Exhibit a piece of common charcoal.

Boron. The basis of the only solid mineral acid, called boracic acid.

Illustration. Exhibit a piece of common borax, which consists of boracic acid combined with soda.

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CLASS IV. METALLOIDS.

Eleven substances are supposed to consist of oxygen combined with bases resembling metals. These bases or imaginary bases, are called metalloids. They are divided into two sections.

Section 1. Bases of Alkalies and Alkaline earths, viz. of Potash, Soda, Lime, Barytes, Strontian, and Magnesia.

Potash. A caustic substance, which, by attracting moisture from the atmosphere, becomes diliquescent.

Illustration. Exhibit a piece of pearlash, which has become soft or diliquescent by having been exposed to the atmosphere three or four days.

Soda. A moderately caustic substance, which, by exposure to the atmosphere, becomes efflorescent.

Illustration. Exhibit a piece of carbonate of soda, which has become mealy or efflorescent on the outside by having been exposed to the atmosphere about a week.*

Lime. A caustic earth, which becomes heated and falls into powder by being moistened with water; and whose specific gravity in the state of a rock is always below three.

Illustration. Exhibit a piece of unslacked lime and slack it on the table in the common way.

Barytes. A caustic earth, which becomes heated and falls into powder by being moistened with water; and whose specific gravity in the state of a rock is above four.

Illustration. Having shewn the process of slacking with the lime, shew the specific gravity of a piece of barytes by the method to be described hereafter.

Strontian. A caustic earth, which becomes heated and falls into powder by being moistened with water; and whose specific gravity in the state of a rock is between three and four.

Illustration. Shew the specific gravity of a piece of strontian.

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* Ammonia is an alkali, but as it is composed of nitrogen and hydrogen, it is placed under nitrogen.

Magnesia. A mild alkaline earth, which forms a bitter salt with some of the acids, and gives an unctious feel to its compounds.

Illustration. Pass around some epsom salts to shew its bitter taste, exhibit a piece of carbonate of magnesia, and pass around specimens of soapstone to shew the unctious feel which it communicates.

Section 2. Bases of earth which are not alkaline. Viz. of Silex, Alumine, Glycine, Zircon, and Yttria.

Silex. A hard earth, which readily fuses with alkalies and forms glass, and does not combine with water so as to form a plastic paste.

Illustration. Exhibit quartz crystals, flints and glass.

Alumine. An earth which is generally soft and combines with water so as to form a plastic paste. It is the principal base of alum and common clay.

Illustration. Exhibit common clay, pipe clay and alum. Exhibit specimens of saphire or unground emery, and shew that, though generally soft, it forms these minerals, which are the hardest substances in nature excepting the diamond.

**Glycine.* An earth which, with some acids, forms sweetish astringent salts.

Illustration. Exhibit a specimen of beryl, of which it is a constituent of about 14 per cent. It is extremely rare and not sufficiently interesting to require any further attention, excepting from those who have much leisure for curious research. Such persons are referred to M'Neven's Brande, Gorham's Chemistry, Silliman's Henry, &c.

**Zircon.* A rough harsh earth, which becomes a yellow jelly in water ; whose specific gravity is about four.

Illustration. Exhibit a specimen. The same remarks apply to this as to the glycine.

**Yttria.* The heaviest of all earths and nearly approaching the metals in its characters.

Illustration. Exhibit a specimen. But few have specimens, as it is extremely rare.

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CLASS V. METALS.

The proper metals are twenty-seven in number. These are divided into four sections. Some in each section ought to be exhibited to the class.

Section 1. *Metals which absorb oxygen with such force as to decompose water, when heated to redness.*

Iron. Magnetic. malleable, very ductile. Its specific gravity is 7.78—that is, it weighs 7 times, 7 tenths and 8 hundreths as much as the same bulk of water. The most useful of all metals.

Manganese. Very hard and brittle, has a strong affinity for oxygen. Specific gravity 6.85—used chiefly for obtaining oxygen.

Tin. Easily melted, not oxydated or rusted at the common temperature. Specific gravity 7.3—Alloyed with lead it forms pewter, and is much used for covering sheets of iron forming the tin-plate.

Zinc. Easily volatilized, forming light cottony flakes, easily burned, strongly attracts oxygen.—Spec. grav. 7.—Alloyed with copper it forms brass.

Section 2. *Metals which absorb oxygen, but not with sufficient force to decompose water.*

(May become acids capable of combining with salifiable bases.)

Arsenic. Very poisonous in the state of a white oxyd, very brittle, volatilized with little heat. Spec. grav. 8.35. Used in medicine.

**Chrome.* Very brittle. Spec. grav. 5.9—Formed into an acid and combined with lead it produces a beautiful yellow.

**Molybdena.* Very brittle, in the state of a native sulphuret it resembles plumbago. Spec. grav. 7.4. Of little or no use in the arts.

**Tungsten.* Hard and brittle. Spec. grav. 17. 5. Not used in the arts.

**Columbium.* Very brittle. Spec. grav. 5.91. Not used in the arts. Found in the sappare of Litchfield, Con.

(Not capable of becoming acids.)

Copper. Elastic and sonorous. Spec. grav. 8.9. Much used in the arts and for coin. Poisonous.

Antimony. Very brittle. Spec. grav. 6.7.—Used in medicine as an emetic.

Bismuth. Brittle, soft, easily melted and volatilized. Spec. grav. 9.8—Used for the most delicate pigments, also in medicine.

**Cobalt.* Brittle. Spec. grav. 8. Used for colouring glass smalt blue.

**Titanium.* Brittle, difficult to fuse. Spec. grav. of the red oxyd is 4.2—Not used in the arts.

**Tellurium.* Brittle, easily melted and volatilized. Spec. grav. 6.1. Not used in the arts.

**Cerium.* Hard and brittle. Spec. grav. not known as it has not been separated from its oxygen. Not used in the arts.

***Uranium*. Very soft, hard to be fused. Spec. grav. 9. Not used in the arts.

Section 3. *Metals which do not receive oxygen excepting from strong acids.*

Gold. Heaviest of all metals excepting platina, most ductile of all metals. Spec. grav. 19.3.—Used in the arts and in coin.

Silver. Very ductile, tenacious and sonorous. Spec. grav. 10.5. Used in the arts and for coin.

Platina. The hardest, heaviest, and most difficult to melt of all metals. Spec. grav. 21. Used for reflectors in telescopes, for crucibles, &c. in the laboratory.

***Palladium*, **Osmium*, **Rhodium*, and **Iridium*. Alloys of platina, possessing some similar properties. Not much known.

Section 4. *Metals which absorb oxygen at limited temperatures, and give it wholly off at higher temperatures.*

Mercury. Fluid not only at the common temperature, but at more than 70 degrees below the freezing point. Spec. grav. 13.5. Much used in medicine and the arts.

Lead. Soft, ductile, easily melted. Spec. grav. 11.35. Used in medicine and the arts universally. Poisonous.

***Nickel*. Hardly malleable, difficult to melt.—Spec. grav. 8.25. Not used in the arts. Always found combined with iron in meteoric stones.

N. B. Those substances to which the asterisk

(*) is prefixed, are either too rare or too imperfectly understood, to require any further notice, than a mere exhibition of the specimens, in such a course of instruction as that proposed in this work. Those, who have leisure to pursue these subjects any farther, are referred to McNeven's Brande, Silliman's Henry, Gorham's Chemistry, Accum's Chemistry, and Coxe's Orfila. For a more full discussion of these nice enquiries, the reader is referred to the last editions of the great works of Thompson and of Murray.

PROPERTIES OF MATTER,

AS THE SUBJECT OF CHEMICAL CHANGES.

CLASS I. POWERS.

AFFINITY.

It is usually divided, according to its application, into simple and elective.

Simple affinity. That application of affinity, whereby the constituent atoms of a body are united, without causing any decomposition.

Illustration. Repeat the experiment with oil, water, and pearlash, as given under simple substances. Here is a mere union of these substances, without the separation of any substance from its union with another.

Application. Make Volatile liniament by putting equal parts by weight of sweet oil and liquid ammonia together in a wine-glass, and stirring the mixture.

Elective affinity. That application of affinity, whereby the constituent atoms of a new compound are united; while one or more substances are thereby excluded from a previous state of union.

Illustration. Put a wine-glass full of pulverized chalk into a pint retort, and pour into the retort water enough to wet it throughout. Then pour in half a gill of diluted sulphuric acid, consisting of one part acid to six parts of water. Sulphate of lime (plaster of paris) will be formed in the retort, by the union of the sulphuric acid and the lime, which is the basis of the chalk. The other constituent of chalk is carbonic acid, (fixed air) which will be crowded out of the union. This will come over in the state of air or gas, and may be received over water like other gases.

Here the lime *elects* the sulphuric acid in preference to the carbonic acid with which it was united, while in the state of chalk ; this application of the principle of affinity is therefore called *elective* affinity.

Application. Obtain carbonic acid, as before directed, from chalk or from marble, and pass it into a decanter of pure cold water, until half the water is displaced by the gas. Shake the decanter violently, holding the thumb over its mouth, for about one minute. The water will absorb the gas and become acidulous. Pass it around in wine glasses among the class, and they will recognize the taste of the common soda waters which are sold in all our towns, though it will be comparatively very weak.

In this application, though the gas is disengaged by elective affinity, it is united to the water by simple affinity.

Affinity unites the constituent atoms of bodies in definite proportions.

Illustration. The experiments required for demonstrating this principle are too nice for an ordinary course of instruction. It may be explained by exhibiting the black scales from a blacksmith's anvil, and common red iron rust. The black scales are composed of 100 parts of iron by weight, combined with 28.68 of oxygen. Iron rust is composed of 100 parts of iron combined with 43 of oxygen. As 28.68 is two thirds of 43, the black scales contain two thirds as much oxygen as the red rust. These proportions are fixed and invariable, and there is no method devised for uniting oxygen and iron in any other proportions.

The same law of definite proportions applies to all metals, salts, acids, &c. ; and modern chemists generally admit, that the *atomic theory* is pretty well established ; or rather, that it may be safely inferred from the doctrine of definite proportions.—This theory supposes, that in all cases where the law of definite proportions governs the combination of atoms, these atoms are united in a numeric ratio. For example, say that an atom of oxygen weighs 1, an atom of iron 7.1 ; then that the black scales from the anvil consist of 1 atom of iron to 2 atoms of oxygen, and the red iron rust consists of 1 atom of iron to 3 atoms of oxygen.

The instructor ought to illustrate this theory by several additional examples. See M'Neven's Exposition of the Atomic Theory, M'Neven's Brande, Gorham's Chemistry, &c.

Application. This principle is very important in the arts. For although the acids, bases of salts, &c. employed in the arts, are not sufficiently pure for accurate experiments, it may be soon learned by practice in what proportions they combine. And since these proportions are always definite, the manufacturer knows how to proportion his mixtures economically. But if his mixtures are not accurately made, still he cannot vary the substance to be produced ; because nature has imposed limits to his compounds, which he cannot control. For example, just such proportions of iron and sulphuric acid form copperas, and definite proportions of sulphuric acid, alumine and potash, form alum, &c.

Affinity changes many of the properties and sensible qualities of substances, which it unites in definite proportions.

Illustration. Put diluted muriatic acid into a wine-glass, 1 of acid to 5 of water. Drop into it dry carbonate of soda, a little at a time until effervescence ceases. Now pass around this liquid in wine-glasses. The class will recognize the taste of common table salt in solution, which affinity had produced by uniting a severe acid with an alkali.

Application. Acids[*] in the stomach may be changed to neutral salts by taking a mild alkali, as carbonate of soda or of lime. If ley be swallowed by accident, an oily substance will change it to soap, and sweetened vinegar and water will change it to acetate of potash, which is less severe.

Affinity unites some substances in all proportions, and does not essentially change their properties or sensible qualities.

Illustration. Pour alcohol, or common rum into water ; the taste of the alcohol will still remain, being reduced only by the insipidity of the water.

Application. Proof spirits, brandy, gin, &c. are made by combining alcohol with water, &c. without changing its essential properties and sensible qualities.

CALORIC.

Caloric is either combined or free.

Combined caloric. That state of caloric, when it does not excite the sensation of heat, nor affect the thermometer ; on acount of its being in combination *with some other substance.* It has been called latent heat, and caloric of fluidity.

Illustration. Put a piece of tinder in the end of the piston of the fire syringe, consisting of cotton cloth dipped in a solution of saltpetre and well dried. Force down the piston suddenly, and the tinder will take fire. Caloric was combined with the air in the syringe before it was compressed; in which state it did not excite the sensation of heat nor inflame the tinder. When it was compressed by the piston, the particles of air were brought too near each other to afford room for so much caloric. Part of it being forced from its state of combination, became free and inflamed the tinder.

Application. There is so much caloric in combination with air, water and other substances about us, that if it were capable of producing the ordinary effects of heat, the whole race of man would be burned to a cinder in a day.*

Caloric, by entering into combination with solids in due proportion, may convert them into liquids, and by encreasing the proportion, may convert the liquids into vapours or gases.

Illustration. Lay a piece of ice on a hot stove or fire shovel, it will soon receive caloric sufficient to become water. Let it remain a little longer and it will combine with caloric enough to become vapour and pass off into the air.

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* Some chemists consider heat as the effect of a *vibratory motion* in the particles of matter. This hypothesis is chiefly founded upon the fact, that a flame may be excited and continued by friction, greatly disproportioned to the combustible substances consumed. But was this experiment ever fairly made in the exhausted receiver of the air pump? If a stick is put in the state of rapid rotatory motion in a lathe, and another stick held against it, a great flame will be produced, by the compression of the air which is forced between the sticks by this rapid motion.

Application. When a kettle of water is placed over the fire, the particles of water next to the bottom first receive caloric enough to become vapour or steam, and attempt to ascend; but the colder water above robs them of a portion of caloric and forces them to remain in the liquid state. When all the water in the kettle has received very nearly the quantity of caloric required for converting the whole into vapor, the particles next to the bottom being converted into steam succeed in ascending to the top and passing off. A succession of such ascending particles of vapor keeps up the bubbling called boiling.

Metals are fused upon the same principle. The same cause also keeps the atmosphere in the state of gas.

More caloric is required for converting liquids into vapor or gas, when the liquids are subject to atmospheric pressure, than when that pressure, or any part of it, is taken off.

Illustration. Fill a Florence flask one third full of water. Fit a stop-cock to its mouth perfectly tight by means of a good sound cork. Suspend the flask with the cock open, over a candle, lamp, or coals, until the water boils. Then turn the stop that all air may be excluded which is driven out by the steam, before the flask is taken down. As soon as the water stops boiling, set the flask on ice, snow, or in cold water, and it will instantly boil. Hold it over the coals and it will not boil. This may be repeated a dozen times with success. The flask may be passed through fifty hands after it is so cool as not to be painful to the hand, and then be returned and still boil when set on ice, snow, or in very cold water. This experiment demonstrates, that water does not require 212 degrees of heat for converting it into vapour. It has been made to boil at 67 degrees; that is 31 degrees below blood heat. Therefore it requires 145 degrees of heat to resist the pressure of the atmosphere.

Application. A boiling pot which boils over with the lid on, will often cease to boil over when the lid is removed. In this case there is not a vacuum between the lid and the water; but the air beneath the lid being driven out by steam, leaves room, without the usual pressure, for the steam continually to follow it to the top of the pot, so as to pass out under the edges of the lid. When the lid is taken off, the pressure of the atmosphere keeps down the water until an additional degree of caloric forces it up again. It cannot be said that the cold air which is let in by cooling the water produces this effect; for it will not, if the heat is but about 212, boil over again with the same fire. A stronger heat is now required.

Caloric enlarges the volume and thereby diminishes the specific gravity of a gas, by entering into and combining with it.

Illustration. Bring a hot coal near an air thermometer, and the air in the bulb will expand so as to force the liquid along the tube.

Application. A heated chimney or stove pipe, by thus expanding the air in it, renders it of less specific gravity than the surrounding air. The heavier air presses into it of course; and thus a current, carrying with it smoke, &c. is continued in that direction. The same application of caloric, on a vast scale, causes winds.

Caloric passes from its combination with one bod into another, which contains less in proportion t its capacity for caloric, until the two bodies are i equilibrio.

Illustration. Put the warm hand upon the bulb of the air thermometer; and the caloric will pass from the hand into the bulb and expand the air in the bulb, until it is as warm as the hand. An equilibrium being thus completed between the hand and the thermometer, the air will become stationary in it. Dip the hand into cold water and apply it again; and caloric will pass from the thermometer into the hand, and the air in it contract until an equilibrium is restored.

Application. Frozen eggs or apples are thus gradually thawed in cold water. Water, not being frozen, though very cold, contains more caloric than they; consequently caloric passes gradually into them from the water until their temperature is raised above freezing. When the hands or feet are frozen, they should be gradually thawed in cold water in the same way.

Caloric expands solids as well as gases by entering into and combining with them.

Illustration. Take the measure of the length of a cold rod of iron, which is about a foot long and cut off square at both ends. Heat it red hot and apply it again to the same measure; and it will be found to be considerably longer. Cool it and apply it again, and it will be found to fit the measure as at first.

Application. This principle causes the pendulums of clocks and balance wheels of watches, to vary in length according to the varying temperature of the weather; and consequently to run faster in cold and slower in hot weather.

Caloric expands liquids, as well as solids and gases, by entering in and combining with them.

Illustration. Fill the bulb of a bolthead with cold alcohol; and on holding it over coals or a candle, the alcohol will expand, and consequently ascend into the neck of the bolthead. A glass tube luted into the neck of a Florence flask, filled with alcohol, will be quite as good.

Application. Thermometers are constructed by confining a liquid (quicksilver or alcohol is generally employed) in a tube with a bulb at the base, containing no air. Degrees are marked against the side of the tube, by which the temperature is indicated as the liquid ascends and descends in the tube. That all thermometers may be made to accord with each other, the boiling and freezing of pure water, are assumed as starting points. Then the space of the tube between these points is cut into a number of equal divisions, each of which is the measure on every degree above and below, as well as between, those points. Fahrenheit divides this space into 180 parts, Reaumur into 80, De Lisle into 150, the Centigrade into 100. We use Fahrenheit, who begins to count at 32 degrees below freezing, making the boiling point at 212.

Caloric is transferred through bodies called conductors; and substances differ greatly in their conducting powers.

Illustration. Procure a pretty long pipe-stem and an iron rod of the same size and length. Make a white wax or beeswax head on one end of each, about the size of a musket ball. Put the other end of each close together on hot coals, passing them through holes in a sheet of tin, set up on one edge, in order to defend the wax from the direct heat of the coals. Then raise the heat of the coals with the hand bellows, and the head of wax on the iron rod will melt soon; whereas the wax on the pipe-stem can scarcely be made to melt. Here the caloric is transferred or conducted through both rods; but the iron being the best conductor of caloric, the wax on it is soonest melted.

Application. An iron stove soon gives off caloric into a room, and soon cools; whereas a brick Russian stove must be heated a long time before it begins to give off caloric into the room, and will not cool in a very long time. Cloaths made of wool and silk are slow conductors of caloric; those made of flax conduct caloric rapidly. As stone is a better conductor of caloric than brick, a stone house has its rooms sooner heated in summer and cooled in winter, than a brick house.

The same substance is a better conductor of caloric if dark coloured or rough, than if bright, polished or light coloured.

Illustration. Place a small tin canister five or six inches from the bulb of an air thermometer with a bright polished side towards it. Fill it with boiling water and let it remain until the canister is thoroughly heated. Pour out the water and fill it again. Now observe how far the liquid is driven along the tube, and mark the farthest point to which it can be driven. Pour out the water and fill it again with water equally hot, having turned a scratched and blackened side of the canister towards the thermometer. The liquid will be driven considerably farther along the tube of the thermometer than before.

Application. A white earthen teapot will keep the tea hot longer than a black one. A bright tin coffee pot will keep the coffee hot longer than a japanned one. Light coloured clothes will keep us cooler in hot weather and warmer in cold weather than dark coloured. For our bodies being warmer than the air in cold weather, caloric passes out through our clothes; but the hot rays of the sun in summer pass through our clothes inwardly.

When solids are converted into liquids caloric is absorbed from the adjoining bodies.

Illustration. Put a few drops of water into a thin viol, and surround it with a mixture of one part of dry fine salt and two parts of dry snow or pounded ice; the water in the viol will be immediately frozen while the ice and salt will become liquid. But if ice or snow cannot be obtained, drop eight parts of powdered glauber's salts into five parts of muriatic acid—or five parts of powdered glaubers salts into four parts of diluted sulphuric acid. The sulphuric acid must be diluted with about five times its bulk of water, and become quite cool, or even cold before it is used. Whichever of these is used, it should be well cooled, and the viol containing the water well cooled; and the viol must be put in as soon as the substances are mixed. More caloric being required for holding these substances in the liquid state, it is taken from the nearest substance containing caloric. Consequently the water in the viol is robbed of so much caloric that it becomes ice.

Application. When snow has commenced thawing by the heat of the sun through the day, it will continue to melt in the evening. During the time it melts in the evening it takes so much caloric from the atmosphere, as often to render it colder than on a preceding evening while water was freezing into ice.

While liquids are converted into vapour or gas, caloric is absorbed from the adjoining bodies.

Illustration. Wet a piece of thin cotton cloth in ether and lay it on the bulb of the air thermometer, and apply a few drops of ether to the cloth frequently, and the air in the bulb will be condensed. The ether should be quite as warm as the thermometer when applied, to make the experiment a fair one. It will then be manifest that the thermometer is not cooled by the liquid ether; but that more caloric being required to convert it into vapour, and the thermometer being nearest, it is robbed of part of its caloric.

Application. Inflamed tumors are cooled on this principle by frequently wetting with ether. Rooms are cooled in hot summer days by sprinkling with water; because the water soon passes into vapor and absorbs some of the caloric from the air of the room.

When liquids become solids, combined caloric is evolved or pressed out and becomes free.

Illustration. Pour a little water on unslacked lime. While the lime appears wet, that is, while the water remains on the surface of the lime, it is cool. But as soon as the water combines chemically with the lime, so that the compound of lime and water are converted into a dry powder, the caloric which held the water in a liquid state is pressed out and becomes free, exciting the sensation of heat.

Application. When the freezing process commences, and water begins to be converted into ice, or vapour into snow, so much caloric is frequently evolved as very sensibly to diminish the severity of the cold.

When vapor or gases become liquids, solids, or more dense vapors or gases, combined caloric of the vapor or gas is evolved or pressed out and becomes free.

Illustration. Collect a viol of muriatic acid gas over mercury, in the manner hereafter to be described. Slip a piece of dry pasteboard across the mouth of the viol, turn it up and set it on the table. Pour in a small quantity of cold water, about equal in bulk to one twentieth of the gas, and the gas will combine with the water and become liquid. At the same time the viol and liquid will become sensibly warmed.

Application. Combustion is explained upon the same principle. For example, successive portions of oxygen coming in contact with heated portions of oil in a lamp or melted tallow of a candle, which are carried up the wick by capillary attraction; the oxygen and oil uniting and forming a more dense gas, a quantity of caloric is pressed out of the oxygen. A continued succession of such combinations pressing out a continued succession of portions of caloric, from the combined to the free state, produces a continued blaze. All combustibles have an affinity for oxygen, and after combustion are found to be combined with oxygen.

Rooms may be warmed by steam upon this principle. Steam holds a great quantity of caloric in combination, and it is readily condensed by a very little cold water, or by the lower temperature of the metallic tubes in which it is confined. On being condensed, as it passes from the state of vapor to the liquid state, caloric is pressed out from its combined state to a free state, and thus warms the rooms.

Free caloric. That state of caloric, when it may excite the sensation of heat and affect the thermometer; being in the state of motion from one body, with which it had been combined, towards another.

Illustration. Set a wine glass, half filled with cold water within about half an inch of the bulb of an air thermometer. Set another wine glass equally near, half filled with cold sulphuric acid. Let them stand a few minutes, until the thermometer appears not to be affected by them. Now empty the glass of sulphuric acid into the water, and the air in the thermometer will be considerably expanded. In this experiment the caloric remains combined with both liquids, while they are separate; and the thermometer is not affected. But when they are mixed, the affinity between sulphuric acid and water unites them so closely as to diminish their bulk and to force part of their caloric from the combined to the free state. It then passes off towards other bodies, and in its way passes into and expands the air of the thermometer.

If the hand be applied to the wine glasses before and after the mixture of the liquids, it will appear, that while combined with the liquids the caloric does not excite the sensation of heat; but that when pressed out into a free state by the mixture, it does produce that sensation.

Application. When we sit by a fire we are warmed by the caloric, which is brought out from its combined state with the oxygen of the atmosphere, into a free state, through the agency of the combustible fuel, as before explained in relation to the combustion of a candle or lamp. Here is no addition of caloric; for the air of the room held all, which now warms us, in combination, before we experienced that sensation.

Free caloric is radiated in all directions from the body from which it is disengaged.

Illustration. Suspend a heated iron ball by a wire, and suspend several small bladders near it on different sides, almost filled with air. They will all be expanded by the free caloric disengaged from the ball.

Application. A stove set in or near the centre of a room will afford as much warmth on each of all its sides, as it would on the one exposed side, if set in a side fire place.

Caloric is reflected by hard polished surfaces, like light.

Illustration. Arrange a pair of concave tin reflectors so that the concave sides may be parallel to each other, at the distance of about six feet apart. Suspend a heated iron ball in the focus of one, and place the bulb of the air thermometer in the focus of the other. Place a fender-plate of tin near the side of the ball towards the thermometer, whose breadth rather exceeds the diameter of the ball, in order to defend the thermometer from the direct action of the caloric. The caloric will be reflected by the reflector near the ball to the other reflector, and by that converged to a focus on the bulb of the thermometer, and will expand the air in the bulb.

The best method for finding the true place for the hot ball and the thermometer is, to darken the room and place a candle in the focus of one and a piece of paper in the focus of the other. These may be varied, until the focal point of the light is accurately found. In that point fix the bulb of the thermometer, and where the candle blaze is placed fix the ball. The side of the bulb of the thermometer, which is to receive the caloric, ought to be smoked with candle, or otherwise blackened.

Application. Polished walls of a room, called hard-finish, will reflect the caloric radiated from a stove, and thereby cause the air of a room to be warmed much more than papered walls. A room lined with sheet tin might be kept warm with very little fire, on this principle.*

ELECTRICITY.†

Remark. Those illustrations, to which the asterisk (*) is prefixed, may be omitted in the course of instruction proposed in this work.

Electrical excitement is the power of attraction and repulsion produced by friction.

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* I have treated caloric as a *material fluid*; which I suppose I may now venture to do, since Professor Hare has had the impudence to demonstrate the absurdity of Davy's vibratory theory. See Amer. Jour. Science, Vol. 4. p. 142.

† Electricity was not considered as belonging to the department of Chemistry by Lavoisier, Henry, Accum and others, who wrote their systems as early as the year 1810, and previous. As some important decompositions are now effected by the power of electricity, a few of its principles ought to be illustrated.

Illustration. Lay a half sheet of paper upon a warm smooth board or table. Rub the paper smartly with a large thick piece of India-rubber, as if rubbing out pencil marks, two or three dozen strokes. Now lift up one end of the paper and let it fall back on the board ; and it will go down with force, being moved by electrical attraction. Hold light down suspended by fine threads near the paper and it will be attracted and repelled alternately.

Application. In cold dry weather, when the atmosphere is always highly charged with the electric fluid, our cloathes often exhibit analagous appearances when we put them off or on in a cold room ; which are to be explained on the same principle.

Electricity is either positive or negative ; and bodies repel each other when similarly electrified and attract each other when contrarily electrified.*

Illustration Suspend light down by a fine thread or a light pith ball, and on bringing near it an excited glass rod it will be attracted. Let it remain in contact with the rod, and in a short time it will become charged with similar or positive electricity and fly off. Now bring an excited bar of sealing wax near it and it will be attracted by the contrary or negative electricity of the wax.

Remark. The best method of exciting the glass rod or bar of wax is, to rub them with a dry clean warm flannel cloth, which had been rubbed with an amalgam made as follows: Melt one part of tin with two parts of zine and stir them well together, Have six parts of mercury made hot in another crucible at the same time. Pour both together into a warm iron mortar and rub them with a pestle until

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* Vitreous and resinous are terms substituted for positive and negative by some.

they become a fine powder. Then put in a little clean hog's lard, and rub the mixture until it becomes a paste. Common unguentum is said to have been used as a tolerable substitute, but I never used it.

Application. A chime of bells may be kept ringing by the application of this principle. Let a row of small bells be suspended by wires and silk threads alternately, from a large horizontal wire. Let metallic balls be suspended from the same wire by silk threads and wires alternately, so as to alternate with the bells; altogether being one with wire to two with silk thread. Now bring the excited glass rod to the large wire, and it will set all the bells to ringing. For the bells suspended by wires will become positively electrified, and attract the balls which are negative. As soon as a ball is charged positively, it will be repelled by that bell and attracted by the next, which is negative, being suspended by silk thread. The ball and last bell will immediately be similarly charged and repel each other, when the whole goes around again as before; and thus a perpetual ringing is continued. But a regularly constructed machine is required for exciting this power sufficiently for ringing a considerable chime.

When the friction is sufficiently strong, sparks like fire, and even a continued stream of flame may be made to pass from the excited body to some substances.

*Illustration. Let there be a communication from the rubber of a common electric machine to the ground. Turn the glass cylinder to produce a suitable degree of friction. The electric fluid will be received on the metallic points or forks the other side of the cylinder and conducted to the metallic coats of cylinders, balls, jars or plates.—Bring the knuckles near any of these coats, and a spark will enter the knuckles with a snapping sound, and some suddenly excited pain, called the electric spark. If it be still more strongly excited, and a metallic substance be brought near to some of the aforesaid coats, a zigzag stream of flame may be passed to it.

Application. This experiment illustrates the phenomena of lightning passing from the clouds in streams or chains as it is called.

Some bodies, called conductors, will transmit the electric fluid along their whole extent and deliver it to the next adjoining substances; others, called non-conductors, arrest the progress of that fluid.

*Illustration. Excite the electric fluid with the common electric machine, and collect it in the Leyden jar, cylinders, &c. covered with tin foil. Now bring near, as before, the end of a glass cylinder, and no fluid will pass off. Also apply various other non-conductors, as a silk handkerchief, &c. Also some bad conductors, as dry wood, &c. when a very feeble spark can hardly be obtained; but if the wood be wet it becomes a conductor. Next bring near a metallic rod or other good conductor, and the fluid will be discharged upon the rod with large brilliant sparks or in a stream.

Application. We are always safe in the most violent thunder storm, if we sit upon a glass stool. Glass windows, if shut, will prevent lightning from entering the window. If we sit upon a dry rail fence we are pretty safe from lightning; but as soon as the fence is wet, it is no defence. Metallic lightning rods, being good conductors of electricity, will attract all the lightning which comes within several rods, in sufficient quantities to endanger the building, provided the lower end of the rod be set pretty deep into the moist earth.

Electricity may be excited by bringing two moistened pieces of metal together which differ considerably in their oxidability; the most oxidizable becoming positively electrified, the least oxidizable, negatively. Electricity thus excited is called GALVANISM.

Illustration. Apply a polished silver quarter moistened with saliva, under the tongue, and a polished copper cent, moistened as before, on the tongue. Whenever their edges are pressed together, they excite a peculiar sensation.

Application. The muscles of animals, particularly of a frog, may be strongly excited, even immediately after death, by attaching a silver probe to a nerve, and bringing a piece of zinc in contact with the muscle. One piece of metal alone has been made to produce considerable effect on the nerves upon this principle. It is said that old ale-drinkers have long observed, that a pleasant sensation is excited by bringing a pewter cup of ale to the lip, which is not produced by a glass of ale ; which effect has been lately explained on the principles of galvanism.

Pairs of metallic plates, made of different metals, arranged so as to alternate with portions of diluted acid, excite the electric fluid so as to produce sparks like fire, and even a continued stream of flame.

*Illustration. Make a wooden trough, and cut it into half inch portions by partitions, each made of a plate of zinc and copper soldered together at the edges. Fill these divided portions with muriatic acid diluted with fifteen times its bulk of water. Now apply a wire to the zinc plate of one end of the trough, and another to the copper plate of the other end. Bring the other ends of the wires near each other, and sparks will pass from one to the other. Or a better method, called Hare's Deflagrator, consists of coiled sheets of zinc and copper, so arranged as to alternate with each other. The whole coil is let down gradually into a vessel containing the diluted acid. The wires being applied as before, a stream of blaze appears, which readily burns every known metal, &c.

Application. By this mode of applying electricity, the greatest heat, known to man, has been produced.

LIGHT.

The different coloured rays of light are reflected according to the arrangement of the constituent atoms of bodies reflecting them; not according to the nature of those atoms.

Illustration. The seven elementary colours may be produced, that is, the seven kinds of rays may be reflected, by variously mixing the following substances. It will then be perceived, that as all the rays may be reflected by these substances, which are either limpid or slightly coloured, the same constituent atoms do not always reflect the same rays. It will of course be inferred, that colour is not inherent in matter, but depends on the arrangement of the constituent atoms of bodies, governed by chemical affinity.

Prepare the following solutions as here directed: 1. Sugar of lead dissolved, 1 to 50 of water by weight—2. Pearlash, 1 to 4 of water—3. Corrosive sublimate, 1 to 30 of water—4. Copperas, 1 to 6 of water—5. Sulphuric acid, 1 to 12 of water—6. Verdegris, 1 to 100 of water—7. Strong liquid ammonia—8. Tincture of red cabbage—9. Tincture of galls—10. Prussiate of potash—11. Nitrate of mercury, made of 1 mercury to 4 of nitric acid, to which is added twice as much water.

By mixing these liquids we make,
Red—One of 5 with one of 8.
Orange—Four of 3 with one of 2.
Limpid with one of 5.
Yellow—Four of 11 with one of 2.
Green—Three of 8 with one of 2.
Ruby red with one of 5.
Blue—Three of 6 with one of 7.
Limpid with one of 5.
Indigo—One of 4 with one of 10.
Violet—Add the red to the indigo.
White—Mix three of 1 with one of 2.
Black—Three of 9 with one of 4.
Limpid with one of 5.

Application. As colours are changed by the various application of the laws of chemical affinity, dyers, limners, &c. ought to be well acquainted with these laws. Mordants sometimes only fix a colour by their affinity for the stuff and for the colouring matter. In other cases they effect a total decomposition of the colouring matter, and thereby produce new colours.

Light decomposes many substances by its direct action upon their elementary constituents.

Illustration. Put oxymuriatic acid gas (chlorine gas) into a vial, cork it tight and set it in a window exposed to the rays of the sun. The next day examine it, and it will be found to consist of muriatic acid and oxygen. The light having separated the oxygen from the muriatic acid.

Application. Prussic acid and many other substances, which are decomposed by the action of light, should be kept in dark cellars, &c. Pictures may be made by wetting paper in muriate of silver or in nitrate of silver, and placing the paper behind glass having a picture on it. The silver will be more or less precipitated in the state of a dark oxyd, of different shades, according to the shades of the picture which intercepted the light.

Light has a powerful action upon vegetables and animals.

Illustration. Fill a bell-glass or large tumbler loosely with mint, hyssop, savory or some other leaves and herbage, collected in the morning before sun-rise. Fill the same up with water, and invert it in a plate filled with water. This operation is best performed in a cistern or tub of water. Set it in a window, exposed to the rays of the sun. Bubbles will soon appear on all parts of the leaves, which, on shaking the whole a little, will rise to the upper part of the vessel. Towards evening immerse it in a tub of water or cistern, and draw out the leaves through water. Now experiment upon this gas, as in other cases, and it will be found to be pure oxygen. Perhaps the best method will be to fill a small wide mouthed vial with it, and test it by dipping an extinguished candle into it; which will be lighted by the heat of the sparks on the wick.

Application. The green colour of vegetables is produced by the action of light. For potatoe vines growing in a dark cellar, and other vegetables excluded from light, are not green. A prisoner long confined in a dungeon looses his usual colour and becomes of a peculiar white, unlike those equally confined where light is admitted.

Light is radiated from many substances, which seem not to belong to the class of luminous bodies; which light is denominated phosphorescence.

Illustration. Rub two pieces of white quartz slightly together in the dark, and they will become luminous.

Application. Some bodies absorb and give off light, as rotten wood, putrid fish, some artificial preparations, &c. Snow absorbs light by day, which it gives off at night; which may be demonstrated by opening a window in a dark night and the room will be actually illuminated considerably.

Those who wish to make the artificial phosphori, called the Bolognian, Canton's and Baldwin's, are referred to M'Neven's Brande, p. 63. The laws of optics belong to the department of Natural Philosophy.

CLASS II. ACIDIFYING SUBSTANCES.

OXYGEN.

Oxygen is found in great abundance in combination with metals, from which it may be disengaged by caloric in the state of gas.

Illustration. Pulverize the black oxyd of manganese in an iron mortar. Fill a gun-barrel one third full with it. Put the end containing the manganese into a fire. A forge is best ; but if the door of a common close stove be taken off and set bottom up, so that the gun-barrel may lie in the notch or hole in the bottom of the door, with the lower end in the fire, and the mouth elevated, it will heat to good advantage. A leaden tube must be fitted to the mouth of the gun-barrel, which leads to the cistern, passing the other end under the funnel in the moveable shelf. Over this the bell-glass or other receiver must stand, filled with water. The leaden tube must be of a size to fill the mouth of the gun-barrel. No luting will be necessary. Merely wind a little wet flax or tow around the pipe and wring it in forcibly. Then suck at the other end of the leaden tube, so as to exhaust considerable of the air, and placing the tongue over the end, wait a moment to see whether the tongue will be released. If not, all is tight. Be sure to have some part of the tube considerably higher than the water of the cistern, by bending it arching upwards. Otherwise water may get into the gun-barrel and cause an explosion.

The apparatus being thus prepared, raise the heat with charcoal or good dry hard wood, and keep the gun-barrel at a moderate red heat. At first collect the gas that comes over in a small open mouth vial; the opodeldoc vials will do. Frequently test it by dipping the hot wick of an extinguished candle into it. When the candle is lighted in it by the sparks and heat of the wick, begin to save it for use. From one to two gallons of the gas may be collected from one third of a common gun-barrel full of the Bennington manganese. But there is great difference in manganese. Some contains a great quantity of carbonate of iron, and carbonic acid will come over some time before the oxygen appears.

Red lead, being oxygen and lead, is quite as good as the manganese; but it is very difficult to clear out the gun-barrel after the process is ended. Whereas manganese is easily emptied out.

Application. This proves, that a part of a solid metallic oxyd is made up of a substance, which when freed from the metal and combined with a due portion of caloric, will become air or a gas. Therefore what would be too hard to be cut with a knife with one proportion of caloric, may be suitable for breathing with another.

Some acids hold their highest proportion of oxygen by so feeble a tenure, that, combined with a base in the state of a salt, they will give it off in a state of gas, when but slightly heated.

Illustration. Saltpetre consists of nitric acid and potash.* If it is coarsely pulverized and put into a gun-barrel and conducted according to the directions for manganese, excepting that the barrel must hardly be heated to redness, the saltpetre will melt

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*The reader must look farther on for an explanation of this salt, &c.

and boil, and soon after oxygen gas will come over. The nitric acid is reduced to nitrous acid, by parting with its highest portion of oxygen; and the saltpetre, called nitrate of potash, is reduced to nitrite of potash. Oxygen obtained in this way will do very well for ordinary experiments; but it is not so pure as that which is obtained from manganese or red lead.

Application. The facility with which oxygen is obtained from saltpetre, is the property on which its use in the manufacture of gun-powder depends. There is another substance, called oxymuriate of potash, from which pure oxygen may be obtained on the same principle with much less heat. But it is very expensive.

Oxygen is the only supporter of combustion in the atmosphere.

Illustration. Having obtained some nitrogen gas (which is the other constituent of the atmosphere) by the process hereafter to be described, fill a small glass cylinder, or wide mouth vial with it, dip a burning candle into it, and the candle will be extinguished. Now fill the same vessel about three fourths full of nitrogen, and fill up the remainder with oxygen. Let the two gases stand a few minutes to mix according to those equilibrium laws which govern their union. Let down into it a short piece of a burning candle by a wire, and it will burn as in common atmospheric air. As the candle would not burn in nitrogen and now does burn after the introduction of oxygen, it is manifest that it is the oxygen which supports the combustion.

Application. When much of the oxygen has been consumed by the breathing of a crowded assembly in a close room, candles do not burn in the room with the same brilliancy.

Oxygen promotes combustion vehemently when pure.

Illustration. Fill a glass cylinder with oxygen, and let down a short piece of a burning candle into it by a wire, and it will burn vehemently.

Application. The necessity for having oxygen diluted with nitrogen is manifest; for if the atmosphere were pure oxygen, all combustible substances, when once inflamed, would burn without controul, to the destruction of all the living beings inhabiting the earth.

Some metals will burn vehemently, after being inflamed, in pure oxygen.

Illustration. Coil up a piece of fine wire, sometimes called harpsicord wire, which is about the size of sewing thread. It will take the most suitable form by winding it spirally and closely around a pipe stem. Let the coil be three or four inches long, with a short piece strait and fitted into a cork, which suits the mouth of a half pint vial. Fill the viol nearly with oxygen, leaving only water enough in it to cover the bottom an inch thick, to defend it from being broken with the globules of hot oxyd of iron, which will fall upon it. Set the vial on the table, stopped with another cork. Now tie a small knot of silk thread on the lower end of the coil, hold a piece of brimstone in the candle till it melts a small spot, blow out the blaze of brimstone and dip in the knot of thread. Be sure that the thread and melted brimstone that adheres to it, all do not exceed in size a large pin-head, All being ready, pull out the cork from the vial, hold the thumb over the mouth while an assistant steadies the viol. Now light the brimstone match and put the coil of wire quickly into the vial, fitting in the cork to which it is attached. Lift up the vial by the neck, that all the class may see the wire burn; which will send of brilliant sparks and make a beautiful exhibition.

Application. From this experiment it appears, that if the oxygen of the atmosphere were not diluted or reduced in power by nitrogen, even iron would not resist combustion. Our iron stoves would burn with the fuel put into them; the smith's hammers and anvil would blaze like tinder.

Oxygen is the acidifying or souring principle.

Illustration. Fill a vial quite full of oxygen, cork it up and set it on the table. Coil the end of a piece of small brass wire around a piece of phosphorus, the size of a pea. Suspend it from the end of a large piece of wire or iron rod, forming a convenient handle to move it with. All being ready, pull the cork out of the vial and hold the thumb upon it; let an assistant steady the vial and hold a candle with the blaze very near the mouth of it. Now take off the thumb, touch the phosphorus to the candle, and in the same instant let it down into the vial of oxygen. It will burn most brilliantly and probably break the vial. A white flocculent substance will line the vial. Whether the vial breaks or not, rinse off this white substance in a tumbler with about half a gill of pure water. Now pass this liquid about in wine glasses, and the class will perceive that the oxygen has given acidity to the phosphorus; that is, it has combined chemically with phosphorus and formed phosphoric acid.

Oxygen is heavier than atmospheric air.

Illustration. Fill a glass cylinder with oxygen gas. Set the mouth of the cylinder upwards, and cover it loosely with a dry piece of paste-board, to prevent its being driven out by the currents of air in the room. Let it stand several minutes; then dip an extinguished candle into it, and it will be lighted. The paste-board being laid on so loosely that the gas could escape, it would escape if lighter than the atmosphere. And if just as heavy, it would mix with it and become too much diluted near the top to light a candle.

Application. As oxygen is one of the constituents of the atmosphere, even in the highest regions which have been explored by aeronauts, and as it is heavier than the other constituent, it follows of course, that oxygen and nitrogen are united by some kind of attraction; otherwise the oxygen would all settle down near the surface of the earth, and the nitrogen would float above it.

Remarks. Oxygen being the most important substance in pneumatic chemistry, it must be kept on hand by the instructor throughout the course. It may be most conveniently kept in bladders. As its properties will be fully developed, when it occurs in aid of experiments on other substances, the class ought not to be detained with any more experiments upon oxygen exclusively.

NOMENCLATURE.

Oxygen enters into combination with acidifiable substances, in several definite proportions, which requires a peculiar nomenclature. When combined in the lower proportions, they are called *oxids* or *oxides*, in the higher proportions they are called *acids.* The proportions of oxygen in the oxyds are expressed by the Greek numerals. As *protoxid, deutoxid, tritoxid,* and *peroxid.* For example, the metal called manganese is said to combine with four definite proportions of oxygen, forming the *protoxid* of *manganese,* the *deutoxid* of *maganese,* the *tritoxid* of *manganese,* and the *peroxid* of *manganese.* Some metals do not unite with oxygen in more than one proportion, some with two, some with three, none more than four.

The proportions of oxygen in acids is expressed by the terminations *ous* and *ic.* As *sulphurous* and *sulphuric* acid. When acids contain more than two proportions of oxygen, the term *hypo* is prefixed to the name next below which it stands. As *hyposulphuric* acid, implies an acid composed of sulphur and the next proportion of oxygen below that contained in sulphuric acid. *Hypo-sulphurous* acid would express the acid which contained a definite proportion of oxygen, next below that contained in sulphurous acid.

Some oxids, which are in the state of gas, are expressed by substituting the adjectives in *ous* and *ic* for the greek numerals. Thus we say *nitrous oxid* and *nitric oxid.*

Those who consider chlorine, &c. simple substaces, have adopted *chloride, iodide,* &c. of course, *chloride of potash, chlorate of potash,* &c. Since so few useful experiments or practical principles require the use of these last terms, it is hardly adviseable to perplex the study with them, in such a course as that proposed in this work. They are all explained at length in M'Neven's Brande, and Gorham's Chemistry.

CHLORINE. (Oxymuriatic acid.*)

Chlorine is obtained in the state of gas from common table salt by the aid of the oxyd of a metal—Sulphuric acid being used also for the purpose of disposing of the soda, which forms the basis of the salt.

Illustration. Put into a retort a pulverized mixture, well rubbed together, consisting of a wine-glass of manganese with twice as much table salt. Then pour into the retort about the same measure of diluted sulphuric acid, consisting of about a gill of sulphuric acid with half as much water. Apply the heat of a candle to the retort, and the chlorine gas will come over. It ought not to be collected in the cistern; for the cistern water will give off a disagreeable odour for many days afterwards. Invert the receiver in a large wash-bowl, and let the water be warm to prevent the absorption of the gas.

Remark. This process is explained on two very different hypotheses. Lavoisier, Berzelius, Murray, Ure and others, say, that the muriatic acid, being disengaged from the soda, and oxygen from the manganese, the muriatic acid unites with a definite proportion of oxygen and forms the oxymuriatic acid, or that this gas consists of muriatic acid with an additional portion of oxygen. Gay Lussac, Davy and others say, that the oxygen disengaged from the manganese unites with a portion of hydrogen, and forms water; which hydrogen, they say, combined with chlorine forms the muriatic acid. The chlorine being thus divested of the hydrogen,

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* I shall treat this substance in such a method, that the student may adopt the theory which best pleases his fancy; for it seems to be a matter of fancy at this day. *I do not believe chlorine is a simple substance;* but I shall so treat the subject, that my opinion will be a matter of indifference to the student.

which held it in the state of muriatic acid, comes over a pure, simple, yellowish-green, suffocating gas.

Application. On this principle, and by a more economical use of the same substances, the same gas is obtained and combined with water, to form the bleaching liquor. But the gas is often disengaged in large quantities from the water, when its temperature is a little raised; which is very suffocating and injurious to the health of workmen. To remedy this inconvenience, the chlorine is united to lime, forming an oxymuriate or chlorate of lime.

Chlorine gas feebly supports combustion, and inflames some substances spontaneously.

Illustration. Fill a glass cylinder with the gas. Immerse a short piece of a burning candle in it, held upright by a wire. It will burn a short time with a deep coloured flame and much dense smoke.

Fill the cylinder again and immerse in it in a small piece of phosphorus, suspended in a coil of wire. It will take fire and burn spontaneously.

Fill the cylinder again and immerse in it in a bent silver spoon, or rather in a small silver mustard spoon, fine filings of copper and of iron. They will soon take fire spontaneously and fly about in bright glimmering flakes.

Remark. Those who consider chlorine as muriatic acid with an additional portion of oxygen, say, the candle burns with the additional portion of oxygen, which the muriatic acid readily parts with. And that the action of the acid, combined with the excess of oxygen, causes the spontaneous combustion. Those who consider chlorine as a simple substance, say, these cases of combustion are evidence that it is entitled to a place in this class with oxygen; but that it supports combustion of itself independently of oxygen.

Application. The facility with which chlorine inflames combustible substances, renders salts made with it very suitable for fire-works. Oxymuriate of potash readily inflames many combustible substances by mere compression in contact with them.

Chlorine extinguishes vegetable colours, if the substances to be operated upon are moistened, or if the chlorine is in a liquid state.

Illustration. Obtain chlorine in the liquid state, as follows: Fill a strong quart decanter one third full of water. Put into it a pulverized mixture, consisting of half a gill by measure of red lead and a gill of common table salt, well rubbed together. After shaking it up, put into the decanter two thirds of a wine glass of sulphuric acid. Put in a ground glass stopper loosely, and shake the decanter half a minute. The atmospheric air and some gas will escape. Now press in the glass stopper perfectly tight and plunge the decanter into a tub or cistern of cold water, just keeping the mouth above water. Agitate it, as much as may be done under water, about once each minute, for fifteen minutes. Now take it out and let the excess of red lead and salt settle. The sulphuric acid must never be in excess. The liquid will now become yellowish-green, and will be tolerable pure; though it will contain a little muriatic acid. Pour a little into a wine-glass, and with it wash out writing from paper, and extinguish the colours from calico.

Application. The liquid chlorine obtained in this way may be kept in vials in a dark cool place, and used for taking spots out of linen &c. It has been employed for fraudulent purposes, to obliterate written instruments so as to write something different in the same place. This may be readily detected by prussiate of potash. For wherever it has been applied, the place will become green on the application of a solution of prussiate of potash.

Chlorine becomes muriatic acid by being deprived of a portion of oxygen, or else by combining with a portion of hydrogen; in this state it is found, constituting an essential part of common table salt, from which it may be obtained in the state of gas by elective affinity.

Illustration. Fill two or three vials or small cylinders with mercury and invert them in the trough. Lute very firmly a pipe bowl to the mouth of a tubulated half pint retort, with half an inch of the stem remaining, which must point upwards.—Having previously dried some fine salt on an earthen plate, put into the retort, through the tubulature, a wine glass full of the salt. Place the retort in a fixed steady position, with the beak in the trough, so as to immerse the pipe bowl and stem under the mercury; but do not place any of the receivers in a situation to collect the gas yet. All being ready, now pour gradually into the retort, through the tubulature, as much strong sulphuric acid as will be sufficient to moisten, or rather wet, the salt. Considerable gas will be given off immediately and pass out at the tubulature; but not more than is necessary for driving out the air and vapour which were in the retort. Put in the stopper, and let the gas waste a few seconds through the pipe stem. Now move one of the receivers to receive the gas, setting it down so as to bring the pipestem a little way into the mouth of the receiver, whether a vial or glass cylinder; because the gas will not ascend into it if merely brought under it, as the practice is when receivers are filled with water. Two or three small receivers will now be soon filled with pure muriatic acid gas. But if a sufficient quantity does not come over, apply a candle to the retort. The salt consists of muriatic acid and soda. In this experiment the soda elects the sulphuric acid and discharges the muriatic, while sulphate of soda, (glauber's salts) is formed and remains in the retort.

Remark. This gas being very acrid, the hands ought to be defended by gloves, and the operator should avoid inhaling it. As it is difficult to procure strong sulphuric acid, a little may be prepared by evaporating slowly in an earthen plate, a small quantity of the common sulphuric acid of the shops. The heat applied must be so moderate as merely to raise a little vapour. If it is set on a stove which is hardly hissing hot, it will evaporate it sufficiently in two or three hours.

Application. On this principle the muriatic acid, called spirits of salt, which is used by artists, may be obtained. For if the gas be passed into a receiver containing water, the water will absorb it and the common liquid muriatic acid of the shops will be formed.

Muriatic acid is strongly absorbed by water or ice.

Illustration. When the muriatic acid has almost ceased to come over by the last described process, take up the retort, pull off the pipe bowl and set the mouth in water, holding the neck in a vertical position. The water will absorb the gas and ascend in the neck of the retort, and at length fill it.

Cut a piece of ice of a suitable form for entering the mouth of one of the receivers, and pass it into the receiver through the mercury. It will absorb the gas, become liquid, and mercury will ascend to fill the vacuum.

Fill a small vial with cold water and invert it in the mercurial trough by holding the finger on its mouth. Now pour a little under one of the jars of muriatic acid gas. The water will absorb the gas and the mercury will ascend as with the ice. Sink a small gallipot into the mercury so as to bring the top of it level with the surface of the mercury. Then with a strait-edged piece of glass, the water of the melted ice, and which was last poured into the receiver and now floats on the surface of the mercury after the receivers are taken up, may be swept into the gallipot. Pass it among the class with a rod in it, by which they may taste the acid.

Application. The strong attraction existing between muriatic acid and water, still exists when the acid is combined with soda in the state of salt. This accounts for the salt's forcing ice into the liquid state when they are used together for a freezing mixture—also when salt is used for thawing out a pump, &c.

Muriatic acid gas extinguishes flame, first enlarging it and giving it a green tinge.

Illustration. Slip a piece of dry paste-board under one of the receivers, turn it up and set it on the table. Now let down a short piece of candle slowly into it. As the candle enters the gas the flame will become broader, dim, and present an outside green or greenish-blue blaze, and then become extinct.

Application. This experiment shews, that the muriatic acid still possesses some faint vestige of that property of the chlorine which enables it to support combustion.

Muriatic acid may be arrested in water standing over common salt, at the moment of its escape; forming the liquid spirits of salt, or the muriatic acid of the shops.

Illustration. Having heated common table salt in a crucible to a moderate red heat and let it cool, put two ounces into a tubulated pint retort. Pour through the tubulature, upon the salt, the same weight of diluted sulphuric acid, consisting of equal measures of the best sulphuric acid of the shops and water, after they had been mixed and cooled. The muriatic acid will be disengaged by elective affinity as before explained; and it will be arrested in the water by that strong attraction which exists between the gas and the water, as before explained. But the sulphate of soda which is formed in the retort being intermixed, the liquid acid is very impure. To separate it from the impurities it must be distilled over. This may be easily done, by fitting the neck of the retort to a receiver, immersed in cold water or surrounded with ice or snow, and applying a very moderate heat to the retort. A sand bath, or coals in a lead pot, will give a due degree of heat.

Application. By this method a physician or an artist may obtain the acid, whose purity he is acquainted with, by very little labour or expense. And in the same experiment we illustrate the doctrine of elective affinity, forcible attraction and the motion of caloric in evaporation and condensation.

FLUORINE.

Fluorine becomes fluoric acid, and dissolves flint and glass; in this state it is found constituting an essential part of fluor spar, from which it may be obtained in the state of gas, by elective affinity.

Illustration. Put into the etching box a tea spoonfull of coarsely pulverized fluor spar, and set the box into a pan of coals placed on bricks upon the table. Pour in strong sulphuric acid, just sufficient to moisten or moderately wet the fluor spar. Fluoric acid will immediately rise up out of the cup, which may be known by its attracting so much vapor from the air as to exhibit the appearance of common steam. As soon as it begins to appear, which will be in a few seconds, lay over the cup a piece of common window glass, large enough to cover its mouth, which had been previously waxed and written upon. Let an assistant instantly apply snow, ice, or cold water, to the upper side of the glass, in order to keep it so cool as to prevent the wax which is on the under side from melting.—Take off the glass in ten seconds and apply another, and so on. Two or three may be applied before the fluor spar and sulphuric acid are renewed. The writing made in the wax will appear beautifully etched upon the glass on scraping off the wax.

The best method of preparing the glass, is to warm or rather heat moderately, the face of a smoothing iron or piece of polished marble, so that white wax or very fine beeswax will melt on being applied to it. Lay the glass flat upon the melted wax, and on sliding it off, it will be very evenly waxed. A dozen pieces or more may be prepared in succession. The writing may be made with the end of a hard stick, nail, &c. Care must be taken to lay the glass perfectly bare throughout all the strokes, or there will be interruptions in the etching.

Remark. Fluor spar is most plentifully obtained from Derbyshire in England. The best known locality in the northern states, is that of the green variety interspersed with purple, discovered at Putney in Vermont, by the Rev. E. D. Andrews. I have received numerous small specimens from there, and used considerable of it in etching.

Application. Any devise, name, stanza, &c. may be etched in this way, not only upon glass, but upon any silicious substance. Common flint, common chalcedony, the carnelion, &c. may be engraved in the same manner. I once etched twenty pieces of glass and a carnelion watch seal, all containing names of persons, within half an hour.

CLASS III. ACIDIFYABLE SUBSTANCES, NOT METALLIC.

HYDROGEN.

Hydrogen and oxygen being the combined constituents forming water, if the oxygen of the water is united to a metal by elective affinity, the hydrogen will come over in the state of gas.

Illustration. Put half a gill of water into a pint retort, to be decomposed. Put into the water a table spoonful of iron filings, for the oxygen of the water to unite with. The oxygen of the water would unite with the iron, forming iron rust or oxyd of iron, in a sufficient length of time; and the hydrogen would come over. Because the oxygen of the water has a stronger affinity for the iron than for the hydrogen, and of course prefers or elects it. As this operation would require several months, put in diluted sulphuric acid, consisting of a wine glass one third full of sulphuric acid, filled up with water, to hasten the process. Hydrogen gas will come over immediately and with great rapidity. If a smaller proportion of sulphuric acid be put in, the gas will come over slower and continue longer. It may be received over water in bell-glasses, tumblers, gas-holders, &c.

The sulphuric acid may be dispensed with, if the water be converted into steam and pass over hot iron. This may be performed by passing an open gun-barrel across a furnace and heating it red hot; while water is boiling at the lower end in a tin cup, box or glass retort with a neck fitted to the gun-barrel. Iron filings or wire may be put into the gun-barrel; but the heated inner surface of the barrel will decompose the water, without the filings or wire, but not so readily.

Application. Earthquakes are probably caused by hydrogen. Iron and water are in contact in the earth, consequently hydrogen is formed. The hydrogen passes into vast caverns and mixes with air. Any spontaneous combustion in the earth, for which there are many causes, would explode the gas; which explosion, if of sufficient extent, would cause an earthquake.

Hydrogen gas burns in a continued blaze, when passed from any vessel into atmospheric air.

Illustration. Put some of the gas into a tubulated bell-glass or common gas-holder, and immerse it beneath the surface of the water in the cistern; having previously fitted a pipestem into a cork with which the tubulature or hole in the top of the gas-holder, is stopped, the upper end of the pipestem being also stopped with a peg. Pull out the peg, and at the same instant apply a candle to the stream of hydrogen which is forced out by the pressure of the water, and it will be lighted and burn steadily with some degree of decripitation. If a stop-cock be used, which is better, no peg will be wanted in the end of the pipe.

Application. This flame was formerly called the philosophic candle; though it was exhibited in a very simple manner. It does not give so much light as some of its compounds, and is not now used for gas lights.

Hydrogen gas explodes if inflamed when inter-

mixed with oxygen—very violently if the oxygen is pure, considerably when the oxygen is combined with nitrogen as in atmospheric air.

Illustration. Mix a quantity of hydrogen and atmospheric air in a tumbler or small bell-glass, one part of hydrogen to two of air by bulk. Fill the gas pistol with water, hold the thumb on the vent hole and set the mouth over one of the funnel holes in the shelf. Pour under and fill the gas pistol with the mixture of air and hydrogen. Having a suitable cork ready and well soaked in water, stop the mouth of the pistol very tight with it. Now raise up the pistol, elevating the mouth so as to point over the heads of the class; remove the thumb from the vent, and at the same instant touch the flame of a candle to it. It will explode and drive the cork to a distance. But if the mixture be made of equal parts of pure oxygen and hydrogen, the explosion will be much more violent.

Application. This exhibits the principle of earthquakes before referred to. Also the inflammability of hydrogen, and shows that oxygen is a supporter of combustion.

Hydrogen gas, though itself combustible, will not support the combustion of other substances.

Illustration. Fill a glass cylinder with hydrogen gas. Raise it up slowly, still retaining it in its inverted position, and carefully settle it down over a candle. When the gas touches the flame it will slightly explode, on account of a little mixture with air at the mouth of the cylinder. After it is so far settled down over the candle as to bring the wick within the gas, it will be extinguished.

Application. The distinction between a combustible substance and a supporter of combustion should be well settled in the mind of the student. Hydrogen and oxygen are good specimens of both.

Hydrogen and oxygen, when united by combustion, form water.

Illustration. Wipe off or cause to be absorbed by a sponge or otherwise, all moisture from the mercury in the trough. Fix a crooked leaden pipe to a stop-cock in the top of the gas-holder of the cistern, so that it shall pass over the side and along on the bottom of the mercurial trough, and rise up above the surface of the mercury about the middle of the trough. Fit a pipestem into the end of the leaden pipe, so that it shall stand upright to the height of about two inches above the surface of the mercury. Having put a sufficient quantity of hydrogen into the gas-holder, turn the stop and let a small quantity of the gas pass out, which must be lighted up by applying a candle to the end of the pipestem. Regulate the blaze by the stop, making it as small as it will burn. But if the blaze is extremely small, it will not burn in the oxygen.

Having previously filled entirely full a perfectly dry small glass cylinder or large mouth vial with oxygen, slide under it a piece of dry paste-board, raise it up and shut it down suddenly over the burning hydrogen, bringing its mouth down to the mercury. It will continue to burn, but will not explode. At length the blaze will become broader, and finally cease. On examination the cylinder will be found to be lined with fine drops of water, and some will run down upon the mercury. No atmospheric air will unite with the oxygen; because, as soon as the blaze comes within the oxygen gas it will expand with the heat, and thus it will be partly forced out while the cylinder is settled down towards the mercury, and of course prevent the entrance of air.

The best method for filling the cylinder with oxygen so as to keep it dry is, to fill it with mercury, and then force in the oxygen from a bladder.

Application. From this experiment it appears, that the burning of one of the most combustible substances with the all powerful supporter of combustion, the liquid is produced which we apply to extinguish flame.

While hydrogen is burning in oxygen and the succession of atoms uniting and forming water, the minute globules of water fly off with such force, as to excite vibrations in a glass vessel, producing sounds.

Illustration. While the above apparatus remains unmoved; light up the hydrogen as before, take up a small bell-glass of oxygen which was filled in the cistern, by sliding across its mouth a piece of wet paste-board, and, removing the paste-board, quickly shut it down over the burning hydrogen so as to bring the mouth very near the mercury, but not quite to touch it. The bell-glass will immediately commence ringing, and if every thing is conducted judiciously with a suitable bell-glass, &c. the sound will almost deafen all present. I think the common bottles used for preserving citrons and other sweet-meats, is the best form. In these the neck is broad and about one third the length of the body.

Keeping the flame chiefly in the neck, while the tip of the flame ascends beyond the shoulder into the broadest part, produces a greater effect. When the sound grows faint, turn the stop a little, so as to enlarge the stream of hydrogen.

Application. It appears from this experiment, that atoms uniting chemically may unite with such force, or may probably come together with such velocity, as to give considerable impetus to the atoms of the compound.

When hydrogen and oxygen are uniting and forming water, much caloric is forced from the combined to the free state.

Illustration. While the above apparatus remains unmoved, light up the hydrogen as before, take up a tubulated bell-glass of oxygen which was filled in the cistern, and shut it down over the burning hydrogen, very near to the mercury as before directed. Having previously stopped the tubulature with a cork, into which was inserted a brass wire holding in coils at its lower end fine iron wire, shavings of zinc, gold and silver leaf, &c. if these substances are quickly brought to the flame of hydrogen they will burn like tinder.

Application. This is an illustration of the principle on which Hare's blow-pipe is constructed.—It is also an illustration of the evolution of caloric when gases are reduced to liquids.*

Hydrogen is much lighter than atmospheric air.

Illustration. Fit a tobacco pipe to the end of a flexible tube. Attach the other end to a stop-cock

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* These three last experiments I have performed several times, apparently to the satisfaction of my pupils, but I never saw either of them performed by any other person, neither have I ever read any description of them.

which is fitted to the top of a gas-holder. Set a bowl of strong soap suds on a table near the cistern.—Having put a large quantity of hydrogen into the gas-holder, turn the stop so as to let out the gas slowly. By applying the pipe bowl to the soap suds, bubbles may be inflated with the hydrogen gas and shaken off, as children inflate them with their breath and throw them. But instead of falling downward as when inflated with the breath, they will ascend and rise to the upper ceiling.

Application. This is the gas with which balloons are inflated. It being but about a fifteenth as heavy as atmospheric air, a large balloon, when inflated with it, will carry up several persons.

Water absorbs and holds in combination a quantity of atmospheric air.

Illustration. Fill the bulb and part of the neck of a bolthead, or a florence flask may do, with river water, or any water which has been considerably agitated in the open air. Tie a thread around the neck at the precise surface of the water. Now suspend it over a candle, or over burning coals, and the water will rise in the neck on account of the expansion of the air contained in the water. Let the heat be continued a little while, but not so as to commence boiling, and numerous bubbles of air will be disengaged and appear in the vessel.

Application. Air gives to water in running streams a kind of briskness, as it is commonly called, which is not found in the water of wells; and on agitating well water a short time in open air it is greatly improved for drinking. The air contained in water is essential to the lives of fish, which has been often shewn by experiment. Some species of fish cannot live in a small still fish pond, which would be healthy if the water was frequently agitated, so as to give it a better opportunity to absorb air.

Water makes an effort to shoot into crystals on freezing, and this crystalline tendency expands its volume and thereby diminishes its specific gravity; probably by inducing minute interstices.

Illustration. Throw a fair specimen of ice upon water and it will float, of course its specific gravity is less than that of the water.

Application. To this principle we are indebted for our ice bridges, erected by nature, during the winter season.

The specific gravity of water is encreased by dissolving a salt in it.

Illustration. Fill two tumblers almost full of water. Let the water of one tumbler be pure, and that of the other contain as much common salt as it will hold at the temperature of pretty cool water. Attach a piece of lead to a small piece of wood, whittling off from either the lead or the wood until it will barely float in the tumbler of salt water. Now put it into the tumbler of fresh water and it will sink to the bottom.

Application. A ship will swim in the ocean with a freight so heavy, that it would sink if sailed into a fresh water river. Persons cast away at sea can swim much easier than they could in fresh water, because the greater specific gravity of the water will help to buoy them up,

NITROGEN.*

Nitrogen and oxygen being the only essential constituents of atmospheric air, if the oxygen be abstracted from an enclosed portion of the atmosphere, the nitrogen will be left in the state of gas.

Illustration. The oxygen may be extracted by burning phosphorus, as directed under the head of simple substances; or more perfectly if the season is not cold, as follows: Mix finely pulverized sulphur and iron filings, rubbing them well together. Then moisten the mixture with water, and place as much of it on the bottom of an inverted wine glass as will lie on it, or place it on any other stand of about the same height. Place this on a shelf of the cistern, or in a large soup plate filled with water. Now shut over this mixture a half gallon bell-glass, or specie bottle of that size, and let it stand about twenty-four hours. The oxygen will be absorbed from the air in the bell-glass, and the water will have ascended to fill the vacancy made by the loss of the oxygen, which is about twenty-one per cent. The remaining gas will be nitrogen.

Application. Whatever consumes the oxygen of the air in a close room, will tend to leave an encreased proportion of nitrogen. Probably the prisoners crowded into the Black Hole of Calcutta, had but very little oxygen to breathe for some time before they died.

Nitrogen gas extinguishes flame and destroys life, if breathed, by excluding oxygen.

Illustration. Immerse a burning candle in a

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* I am very glad to find *nitrogen* used by Brande instead of *azote*, which Gorham has very unadvisedly, adopted.

small jar of it, and it will be extinguished. Fill a small jar entirely full of the gas, slip a piece of wet paste-board across its mouth and turn it up. Take a live mouse into the hand, having a leathern glove on it to defend it from the bite of the mouse, and drop it into the jar, instantly covering it again. The mouse will expire in a short time, though not so soon as in some other gases.

Application. Since oxygen and nitrogen are the only essential constituents of the atmosphere, and since nitrogen extinguishes flame and destroys life, it is manifest that oxygen is the only supporter of combustion and animal respiration in the atmosphere.

Nitrogen gas is the lightest of the constituents of atmospheric air.

Illustration. Extinguish a candle as before directed in a jar of nitrogen gas. Then cover it loosely with dry paste-board, so that the motion of the air may not drive it out, and let it stand a while. Afterwards, or at least after a few trials, the candle will not be extinguished; because the nitrogen, being lighter than atmospheric air, will have ascended, and common air will have taken its place.

Application. Though oxygen and nitrogen in open space, mix in an equilibrium proportion; when one of them is in excess, or in any manner separated from its state of union, it will seek its place according to its specific gravity. Consequently a disunited quantity of oxygen will settle downwards, and that of nitrogen will ascend. So that when much oxygen is consumed by a crowd of persons in a close room, the excess of nitrogen will ascend and render the air near the upper ceiling very unfit for breathing, while the air lower down is more suitable for respiration.

About seventy-nine per cent of nitrogen gas, mixed with twenty-one per cent of oxygen, will form artificial air, in all respects similar to atmospheric air.

Illustration. Take four glass cylinders, as nearly equal in size and form as can be procured, and fill them as follows: The first with nitrogen, the second with oxygen, the third with four measures of nitrogen and one measure of oxygen, and let the fourth remain filled with atmospheric air. Turn them all up, leaving them covered with pieces of wet paste-board, excepting the fourth, which may be open. Light a short piece of candle, which is suspended by a wire coiled around at its lower end. Let it burn some time with a large wick, which should be spread out wide and full of sparks. Now immerse the blazing candle in the nitrogen, and it will be extinguished—then quickly immerse it in the oxygen and it will be re-lighted—next immerse it alternately several times in the cylinders of artificial and natural air, and it will burn alike in both.

Application. By this experiment we see at one view the nature of the two constituents of the air in their separate and in their combined state. Though these proportions are temporarily varied in the atmosphere of confined rooms, and sometimes in large cities and other places, nature has provided remedies for such contingencies. A considerable supply of oxygen is drawn from the vegetable kingdom, which was illustrated under oxygen. There are other means prescribed for equallizing the proportions of those gases, according to their equilibrium principle.

The production of nitrogen cannot always be accounted for. There is a small hill, or rather an ascent of ground, in the town of Hosick, in the state of New-York, from which continually issues immense quantities of nitrogen gas. Wherever the little rivulets pass over any part of four or five acres of this hill, nitrogen gas continually bubbles through the water. Dr. L. C. Beck and myself collected and tested this gas on the 17th of Aug. 1821. It is situated near the east boundary line of the state, about six miles southwesterly from Bennington, Vt. Vid. Report of the Geological survey of Rensselaer county, p. 29.

Atmospheric air holds in suspension more or less of aqueous vapour.

Illustration. Put a little common table salt into a wine-glass, and pour on it strong sulphuric acid sufficient to wet it. Muriatic acid gas will be disengaged, as observed under chlorine. This gas was then invisible, but it was seen by an experiment that it attracted water powerfully. In this experiment it will attract water from the air and condense it so as to become visible, and appear like steam.

Application. This experiment demonstrates, that clouds are not the only repositories of aqueous vapour in the atmosphere; but that it is held in suspension in its most clear and transparent state. Neither aqueous vapour, hydrogen, nor carbonic acid are constituents of the atmosphere, however, as some chemists have absurdly observed. It would not be more absurd to call dust and leaves constituents of the atmosphere, or driftwood and mud constituent parts of water.

Atmospheric air presses with considerable force on all surfaces exposed to it.

Illustration. Fill a wine glass perfectly full of water, cover it with a piece of writing paper, press the hand upon it and invert it. The water will be sustained in the glass by the upward pressure of the air.

Fill a small strong glass tube with mercury, which is closed at one end. more than thirty inches long, three feet is about a suitable length. Hold the thumb strongly on the open end and invert it, placing the open end in the mercurial trough. The mercury will sink down leaving a perfect or Torricellian vacuum, at the top of from five to eight inches; a column of from twenty-eight to thirty-one inches, being sustained in the tube by the pressure of the atmosphere upon the surface of the mercury in the trough.

Application. Atmospheric pressure varies according to the temperature, quantity of moisture contained in it, and the elevation of the place where bodies are situated. As the height of the column of mercury varies in a direct ratio of the variation of pressure, an instrument, called a barometer, is conveniently constructed for ascertaining the quantity of variation.

As mercury is thirteen times and a half the weight of water, it follows that a column of water may be raised thirteen and a half times as high as a column of mercury by atmospheric pressure. For example, water may be raised by what is called a suction pump to the height of between thirty-one and thirty-five feet.

The average pressure of the atmosphere is about fifteen pounds upon every square inch. More than a ton weight presses upon a middling size man.

Atmospheric air can be weighed in scales by a direct process.

Illustration. Fit a stop-cock to a florence flask as in the experiment of boiling water with snow. Heat the flask, almost to its melting point, in order to drive out the atmospheric air; and turn the stop while at its highest heat. Take it from the fire and weigh it accurately. Now turn back the stop and weigh it again, and it will be found to weigh more than before. By measuring the flask with water, the measure of atmospheric air will be known; and, though the last portion of air will not be driven out by heat, it may be brought so near to a vacuum as to give a pretty satisfactory result. The air could be exhausted more effectually by a good air pump.

Application. The elasticity and expansive power of air is here shown. By the same method any gas can be weighed; differing only in applying the mouth of the stop-cock to the tube of a bladder's neck, or whatever contains the gas to be weighed, and filling the flask in this way with the gas instead of atmospheric air.

Remark. This experiment, as exhibited before a class, is rather intended to shew the principle, than to arrive at a correct result. Far more time would be required to ascertain the temperature and weight of the atmosphere at the time, &c. than could be afforded in the course here proposed.

Nitrogen is found combined with its highest proportion of oxygen in the saltpetre, from which it may be obtained by elective affinity.

Illustration. Put into a tubulated pint retort about a wine-glass full of pulverized saltpetre, and pour upon it, through the tubulature, strong sulphuric acid sufficient to wet it, or about two thirds as much by weight as there is of the saltpetre. Having previously luted the neck of the retort into a receiver containing a gill of water which has a stoppered tubulature; now set the retort into a lead pot with coals and raise the heat very moderately. Leave out the stopper a while, for the air to pass out. Then put in the stopper rather loosely, but regulate it according to the pressure of the gas. The nitric acid, (aqua fortis) will come over in the state of gas, or rather in connexion with the vapour of water. It will be absorbed by the water of the receiver. After the process is finished, pass around some of the acid in wine glasses with a rod, and the class will recognize the taste of diluted aqua fortis, or nitric acid.

Application. On this principle the aqua fortis of the shops is manufactured. Iron retorts are used in the manufacture of it in the large way; therefore it will generally give the test of iron with prussic acid. As saltpetre always contains muriate of soda, muriatic acid will be contained in the aqua fortis of the shops; consequently will generally dissolve gold, unless it is removed by nitrate of silver, (lunar caustic.)

Nitric acid may be reduced to nitrous acid and nitric oxyd, by yielding part of its oxygen to a metal.

Illustration. Put into a very small retort, a gill retort is best, a table spoonful of copper filings—About one fourth as much mercury will do, but not so well. Then pour into it about two spoonfuls of nitric acid, diluted with three or four times as much water. Put the beak of the retort into the cistern under a receiver, and apply the heat of a candle or a pan of coals to the retort. The heat must be uniformly applied, or the gas may be a little condensed in the retort, and the water will rush into it. The gas will soon come over; but the first will be mixed with atmospheric air, of a reddish colour, and should be allowed to escape thro' the water of the cistern. It will soon pass into the receiver in a colourless state. This gas is the *nitric oxyd* or the dentoxyd of nitrogen; for the copper filings have taken up so much oxygen as not to leave a sufficient proportion of oxygen to form an acid.

After a sufficient quantity has been collected, fill a small glass cylinder half full of oxygen (atmospheric air will do) and then fill it up with nitric oxyd. It will immediately take another portion of oxygen and become *nitrous acid*. This gas is readily distinguished from the nitric oxyd, by its deep orange colour. If the glass cylinder be turned up and a burning candle be immersed in it, the candle will continue to burn with considerable brilliancy.

Application. In this experiment we begin with the highest state of oxydation which nitrogen is capable of. Having no convenient method for reducing it one grade only, we reduce it through two proportions at once—carrying it down to the state of an oxyd. Then letting it come in contact with oxygen, whether pure or mixed with nitrogen, it takes a proportion of oxygen, intermediate between nitric oxyd and nitric acid, and forms nitrous acid.

Nitric acid may be reduced to nitrous oxyd (the exhilarating gas) *by heating it when chemically combined with ammonia.*

Illustration. Prepare the salt called nitrate of ammonia, according to the directions to be given further on. If the salt is prepared in crystals, let them be melted and evaporated to a dry powder in an open earthen plate with a slow heat. Put the salt into a retort. which may be about one fourth part filled. Apply a tin tube to the beak of the retort about three feet long, to prevent accidents which generally happen without it, by breaking the retort with water when highly heated. No luting is necessary, wet tow or flax will be sufficient.—Now set the retort into a lead pot with coals and raise the heat with the hand bellows. After the salt has melted, and white vapours begin to appear in the retort, apply the beak to the cistern under the receiver. A great quantity of the gas will soon come over; and it will continue until all the salt, or nearly all, disappears.

This nitrous oxyd gas may be breathed in small quantities by the members of the class, about a pint to each, without injury. It will exhiliarate slightly, and the taste is sweetish and pleasant. If breathed in large quantities, as about two gallons at once, respired a dozen times, it intoxicates and suspends the power of reasoning. It is unquestionably injurious to health; but being generally administered to the young and healthy, they endure it, mostly, without any bad consequences. Brande says it cannot be breathed with impunity.*

A burning candle let down into this gas has its flame increased and it is always surrounded with a purplish ring or halo.

Application. By these two last illustrations it appears, that nitrogen combines with oxygen in four definite proportions. And that, beginning with the highest proportion it may be reduced to the other three. In reducing it to the lowest state, the nitrous oxyd, the rationale is thus given by chemists. The nitrate of ammonia consists of nitric acid combined with ammonia; and ammonia is a compound of nitrogen and hydrogen. When considerable heat is applied to this salt, the hydrogen of the ammonia unites with the highest portion of the oxygen of the nitric acid and forms water. This comes over in the state of white vapour, which appears first. The nitric is thus reduced to a lower state of oxydation. At the same time the nitrogen of the ammonia takes away another proportion of oxygen and becomes nitrous oxyd, leaving the nitrogen of the nitric acid just oxygen enough to form nitrous oxyd also.

Nitrogen and hydrogen combined form an alkaline compound called ammonia, hartshorn, or volatile alkali.

Illustration. Fill a florence flask with nitrogen.

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* Several persons have lately employed themselves in peddling this gas about the country, who call their vulgar frolicks, lectures on chemistry. All sensible citizens ought to discountenance such gross outrages upon decency, which tend to reduce the science to the level of a puppet-show.

Pulverize iron filings so as to make them almost into an impalpable powder. Pour a small quantity of water upon them, so as to be enabled to make them adhere in the form of little balls, twice or thrice the size of peas. Drop about a dozen of these balls into the flask—care being taken not to leave the flask open but an instant at a time when dropping in the balls; as the nitrogen will ascend. After a considerable time small quantities of hydrogen will be produced by the decomposition of the water with which the balls of iron filings are moistened. At the instant of the disengagement of the hydrogen, or rather while it is in an evanescent state, the nitrogen unites with it and forms ammonia in the state of gas. This may barely be perceived by the scent; but if muriatic acid gas be passed into the flask, muriate of ammonia, or sal ammoniac, will be formed in a small quantity and adhere to the side of the flask.

N. B. I have sometimes failed in this experiment, without being able to assign a reason for the failure.

Application. This experiment demonstrates the compound nature of ammonia. But as ammonia is produced in great abundance in nature, and has most of its properties in common with the alkalies, it will be treated in connexion with the other alkalies.

SULPHUR.

Sulphur on being inflamed in atmospheric air, will unite with a definite proportion of oxygen and form sulphurous acid gas.

Illustration. Cover the bottom of a small plate a quarter of an inch deep with water. Put a small piece of common brimstone in the centre of the plate, elevated on a piece of earthen, marble or other substance which will not burn or dissolve in water. Now inflame the sulphur with a candle, and shut over it a tubulated bell-glass, or a tumbler with a hole in the bottom. This vessel must be of a size just to shut down within the rim of the plate. At first take the stopper out and raise the bell-glass a little above the water, to give passage to a current of air. Regulate this by the progress of the burning sulphur. After the bell-glass appears well filled with a white vapour, shut it down close and tighten the stopper. The water in the plate will absorb the sulphurous acid gas in about fifteen minutes. Pour part of this water into wine glasses and pass it around with tasting rods, and the class will perceive the nauseous sulphurous astringent taste, peculiar to this acid. In the mean time wet several substances, coloured with vegetable colouring matter, and it will extinguish many of them, but not all. A yellow straw braid will become whitened in it; and some colours on calico will be extinguished. The liquid sulphurous acid looses this property by keeping long.

Application. This acid is used by milliners both in the liquid and in the gaseous state for bleaching straw bonnets. If old yellow straw braid is soaked a while in water and then suspended inside of a noheaded barrel or hogshead, and brimstone is inflamed at the bottom of the cask, and suffered to commence burning thorougly, then the top covered over, the straw will soon become whitened by the action of this acid.

Sulphur, on being inflamed in atmospheric air, if previously pulverized and mixed with a portion of saltpetre, will unite with its highest definite proportion of oxygen and form sulphuric acid, or oil of vitriol.

Illustration. Dry some saltpetre on a plate. Then pulverize it very thorougly, and mix it with about four times as much sulphur, (in the large way eight times as much sulphur is used,) and rub them intimately together. Now proceed in all respects as in producing sulphurous acid, above described ; and the additional portion of oxygen furnished by the saltpetre will perfect the process. After the water has absorbed the acid, pass some of it around in wine glasses with tasting rods, and the class will recognize the clean pleasant sour taste of the sulphuric acid, or oil of vitriol, in a weak or diluted state. It is distinguished from all other acids by its charring or blackening all vegetable substances.

Application. The oil of vitriol of the shops is made on the same principle. Leaden chambers being substituted for the bell-glass, and the floor is covered with water. It is at first obtained in a very diluted state. It is then slowly evaporated, until it comes to a suitable strength for the market. When this, or any other acid, is combined with the smallest quantity of water, which can hold it in the liquid state, it is called concentrated acid. To produce this, the acid itself is distilled over, after the evaporation of the water is finished. But almost any experiment may be performed with the acid which is prepared by slowly evaporating the water from it in an open plate.

Remark. Sulphuric acid is the key to most chemical analyses. It is made by a direct process. Whereas nitric acid and muriatic acid, being the other two powerful acids, are obtained from saltpetre and from common table salt, by the agency of sulphuric acid.

Sulphur may be combined with hydrogen and form the essence of most of the nauseous scents, called sulphuretted hydrogen gas.

Illustration. Mix about equal bulks of finely pulverized iron filings and pulverized sulphur. Put this mixture into a crucible; covering it over by inverting in it the crucible next smaller in size, of the nest of crucibles to which it belongs. Set upon hot coals and melt the mixture—let it remain until the blue blaze which leaks out between the crucibles, ceases. Now empty it out, which will be the artificial *sulphuret of iron.* Next proceed with this in all respects, as directed for obtaining hydrogen gas with this addition; that after the sulphuret and the diluted sulphuric acid are mixed in the retort, the heat of the candle must be applied to the retort.

This gas must not be collected in the cistern; but the receiver must be filled with pure clean rain or river water and inverted in a wash bowl or some other convenient vessel.

Application. This is the gas which is generated in all dirty sinks and other places abounding in such filthy substances.

Sulphuretted hydrogen gas explodes on being inflamed in oxygen.

Illustration. Mix it with oxygen and explode it in the gas pistol in all respects as directed with pure hydrogen.

Application. There may possibly be a sufficient quantity of this gas generated about the kitchens and sinks of filthy housekeepers, to explode with the oxygen of the atmosphere. This would be a dangerous method of purification "by fire."

Sulphuretted hydrogen gas is absorbed rapidly by water; and, in the liquid state, gives a dark or black tinge to many metals.

Illustration. While the gas is coming over, as before mentioned, let some pass into a decanter, which is filled with rain water and inverted, until half the water runs out. Put the thumb over the mouth and shake the decanter violently. It will immediately absorb the gas. Now pour a little into a wine glass and drop in a little sugar of lead and it will be blackened. Copperas, blue vitriol, white vitriol, and other metallic salts may be dropped into different glasses of the liquid, and all will receive different shades of colour. A piece of silver coin will also become brown if immersed in it a while, especially in the roughest parts of it.

Application. When lead is suspended in water, this liquid is a ready test. Silver spoons, &c. often exhibit dark coloured spots, which appear unaccountable to housekeepers. These are generally caused by liquid sulphuretted hydrogen, generated about filthy sinks, &c. Ladies who paint their faces with a cosmetic whose basis is bismuth or other metal, often become tawny by approaching an old dock or sewer.

Many natural springs are highly charged with sulphuretted hydrogen. They are always useful in cutaneous eruptions; and are generally called Harrowgate springs, from their resembling the Harrowgate waters in England. They are distinguished by the smell of sulphur, or by testing with sugar of lead.

PHOSPHORUS.

Remark. The process for obtaining phosphorus is too laborious and difficult, to be performed in the course proposed in this work. It is obtained from animal bones, which consist chiefly of phosphoric acid and lime. The lime is easily disposed of by soaking the bones in diluted sulphuric acid, after they had been burned to whiteness and pulverized. But to separate the oxygen from the phosphorus, after the phosphoric acid is freed from the lime, requires a high and long continued heat; and it requires considerable experience to conduct this part of the process with success. It may be purchased at a dollar and a half or two dollars per ounce. Half an ounce will be sufficient for a course of instruction.

Phosphorus slowly decomposes water, by combining with a little oxygen, forming the oxyd of phosphorous.

Illustration. Expose a stick of phosphorus to water several days in a vial, and the outside will be covered with a white substance, which is the oxyd of phosphorus. The oxyd is more inflammable than pure phosphorus. If a little be scraped off and exposed to the rays of the sun a short time it will take fire.

Application. Sticks of phosphorus kept in vials of water in the common way, are always covered on the outside with the oxyd. I once set a gallipot in a desk in Rutland court-house, Vermont, to the inside of which a little oxyd of phosphorus adhered. The weather was extremely cold, and it stood undisturbed and forgotten for several days. At length a crowded assembly occupying the room one evening, and the temperature of the air being considerably raised, it took fire spontaneously and burned rapidly. If a vial be heated a little, and a piece of phosphorus attached to the end of a wire be rubbed about the inside of the viol, in a half melted state, so as to coat it, this will be the phosphoric match vial. This being the oxyd of phosphorus, if a little be taken out and exposed to the air, if the weather is not very cold, it will take fire spontaneously. The vial must be kept corked— and even when it is preparing, it may take fire and require the vial to be stopped a moment until it is extinguished.

By light friction phosphorus becomes oxydated, and during the process a partial combustion and illumination takes place.

Illustration. Rub a stick of phosphorus lightly on a smooth pine board. The phosphorus which is left on the board will be luminous in the dark, and by blowing upon it a fiery appearance will appear and vanish, and exhibit undulating waves of light.

Application. Letters or even sentences may be written on board ceilings, &c. which may be read in the dark for fifteen or twenty minutes. During their illumination, the phosphorus is manifestly in a state of imperfect combustion and becomes oxydated.

Phosphorus, on being inflamed in atmospheric air, will unite with its highest definite proportion of oxygen and form phosphoric acid.

[illegible] as directed for [illegible]. But the bell-glass need [illegible], and it must be shut down very suddenly and kept closed, immediately after the phosphorus is inflamed. A very dense white substance will immediately fill the bell-glass. After the water in the plate has absorbed the white vapour, pour [illegible] it into wine glasses and pass it around with [illegible]. The class will perceive that an acid is formed, which is absorbed by the water.

Application. This acid is not much used. It is [illegible] found in animal bones, as before observed.

Phosphorus may be inflamed under water by [illegible] of oxygen.

[illegible] Put a considerable quantity of [illegible] cylindric [illegible] with cold water, and put in [illegible]

[illegible]

put in. After the open end of the tube is brought in contact with the salt, the thumb may be raised up and pressed down, so as to furnish the quantity of acid required to continue the flame.

The phosphorus may be inflamed also by forcing a stream of oxygen upon the phosphorus, through a tin tube from a bladder. But in this case the water must be hot, nearly at boiling heat.

Application. This experiment proves, that combustion may be supported in defiance of water, which we generally consider as having unlimited power over fire.

Phosphorus may be made to unite with hydrogen, forming a compound which explodes and burns spontaneously in atmospheric air, called phosphuretted hydrogen gas.

Illustration. Phosphorus may be made to decompose water, and to unite with the hydrogen of the water in its evanescent state. But it seems to require the presence of an alkali to create in it, in some unexplained manner, a pre-disposition to decompose the water.

The following method was obligingly communicated to me in a letter by Prof. Silliman. Put into a retort a quantity of unslacked lime, about enough to fill the retort half full after it is slacked. Put in water enough to slack the lime. Put in about one-third, by measure, as much pearlash as lime, after the lime has slacked. Now fill the retort to the bend of the neck with water. Shake up the mixture, and immediately put in some shavings of phosphorus. A stick an inch in length shaved up will be sufficient, if the retort holds a pint. Now shake up the whole mixture, and set the retort into a lead pot, and apply heat. Let the beak be turned directly upwards, and fill it entirely full of water. Raise the heat until a bubble or two appears at the beak of the retort, and explodes. Now fill up the retort quite full of water, if any has run over; place the thumb upon the beak, and stop it close, to prevent atmospheric air from entering it, while the beak is turned down and immersed in the cistern. Raise the heat gradually, and the gas will soon fill the bend of the neck, and gradually approach the beak; and as the bubbles begin to be expelled from the beak, they take fire and explode. If the air of the room be kept still, the corrona or twisting wreath of smoke will ascend in an elegant form, after each explosion.

Application. This is an exhibition of the Jack-o'lantern, so often seen about places where animals are putrifying in damp ground. But nature has a method of combining the phosphuretted hydrogen with something, which causes it to burn more steadily and to endure longer.

Phosphuretted hydrogen gas explodes spontaneously, and with great brilliancy in oxygen gas.

Illustration. While the bubbles of sulphuretted hydrogen gas are ascending, pass the beak of the retort under a hole in the shelf, over which is set a strong bell-glass, with about a pint of oxygen in the upper part of it. After a bubble has ascended through the water of the bell-glass and comes in contact with the oxygen, it will explode with a brilliant illumination.

Application. Here the two most combustible substances in nature, hydrogen and phosphorus, meet the great supporter of combustion, oxygen. We should of course expect spontaneous combustion.

Phosphorus dissolves in warm oil, and in that state is luminous in the dark when exposed to atmospheric air.

Illustration. Fill an ounce vial two thirds full of sweet oil. Put some shavings of phosphorus into it; about half an inch of a common stick will be sufficient. Hold the vial near the fire, until it is about as hot as can be borne by the hand, and keep it at this temperature until the phosphorus is melted. Now if the cork is taken out, the upper part of the vial will become luminous in the dark by the admission of air. Cover all the lights in the room, pour two or three tea-spoonfuls of it into the hand, and rub it thoroughly over a boy's face and hair, and let him show himself to the class. His face will be singularly luminous, and his hair will exhibit a kind of undulating flame. It must not be forgotten, in this experiment, that the vial is to be very warm, so that the oil may be of a temperature about equal to blood heat whenever it is to be applied.

Application. Although many luminous meteors traverse the atmosphere, called shooting stars, &c. which have never been subjected to analysis; yet these three last experiments go far towards a solution of such phenomena.

CARBON.

Remark. Carbon is pure in the state of a diamond only. Common charcoal is always combined with a little oxygen. Carbon is abundant in nature in various states. In the pitcoal it exists in combination with a little oxygen, bitumen, sulphur, &c. In the anthracite or glance coal it is more pure than in any other state, excepting the diamond. Combined with oxygen and forming a gas, it floats in the atmosphere. It forms a constituent part of marble, of chalk, of all vegetable and animal matter, &c.

Charcoal, when cold, absorbs sulphuretted hydrogen gas, ammoniacal gas, carburetted hydrogen gas, carbonic acid gas, &c. and gives them off again when heated.

Illustration. Prepare these gases according to the directions heretofore given, and hereafter to be given; fill small glass cylinders or broad mouthed vials with them separately, and place them over mercury. Cut pieces of charcoal of a size which will easily enter the mouths of the glass cylinders. Take the pieces separately into the small tongs and hold them over a hot fire, until they become red hot. Take them from the fire and scrape off the outside a little, and plunge them into mercury to cool without coming in contact with air. After they are perfectly cooled, pass them separately into the several cylinders of gas, and a considerable quantity of each will be absorbed, and the mercury will ascend to fill the vacuum. After these pieces of coal are saturated, draw them out through mercury (at least one or two of them) and heat them again. On applying them a second time, it will be found that the heat has driven out the gases, as they will again absorb them as before.

A little mercury will be found pressed into the pores of the coal; but this does not affect the experiment, as the coal will absorb the gases equally well.

Application. There is not an experiment known in chemistry, which explains more of the practical principles of agriculture and domestic economy, than this. All the gases which are produced when animal matter passes into a state of putrefaction being absorbed by it, it is very important in resisting and checking the progress of putrefaction. A tooth-powder, made by heating finely pulverized charcoal to redness in an iron skillet, and pouring it while hot into a bowl of clean water, is the best of all known substances to preserve the teeth from decay, or to prevent further decay after it had commenced. For the gases being all driven out by heat, the charcoal absorbs water and sinks in it. If kept in a bottle, it will remain under water, defended from the gases, and if shaken up and a tea-spoonful be taken occasionally into the mouth, and the teeth rubbed with it, every thing impure will be absorbed.

Putrid meat will become purified by immersing it in a similar preparation. Putrid water is also purified by pouring into it heated charcoal powder, &c. &c.

Carbinaceous manures, as rotted straw, leaves, &c. furnish food for vegetables upon the same principle. In the cool season of night they absorb carbonic acid, carburetted hydrogen, ammonia, &c. which they give off under the heating rays of the sun during the day to the absorbent vessels of the fibrous roots of plants.

Charcoal. if exposed to oxygen gas in a state of ignition, will combine with it, and form carbonic acid gas.

Illustration. Fill a glass tumbler with oxygen gas in the cistern, slip across its mouth a piece of paste-board, turn it up and set it near the mercurial trough. Expose a small piece of charcoal to a strong heat, holding it in the tongs until it is red hot and burning. Now lay it upon the surface of the mercury, and holding the paste-board preſsed upon the tumbler, bring it, with the top downwards, over the burning charcoal. Quickly remove the paste-board, and shut the tumbler closely over the coal. It will burn, throwing off bright sparks, until so much of it has become a gas and combined with the oxygen, as to convert the whole into carbonic acid. The bulk of the gas will neither increase nor diminish, but become specifically heavier.

Now draw out the coal through the mercury, slip the paste-board across the mouth of the tumbler, turn it up and set it on the table. Immerse a burning candle in it, and it will be extinguished.—Test it also with limpid lime water. This may be performed most conveniently, by carefully letting down into it a low glass cup of lime water. It will soon be covered with a white or grey pellicle. A pretty large watch glass will do, if it is not convenient to obtain any other.

Application. A kettle of coals is frequently set into a close bed-room on a cold night. Carbonic acid gas is formed by the union of the charcoal with the oxygen of the atmosphere, which frequently destroys life.

Carbonic acid exists in combination with lime, forming chalk, common limestone, or marble, from which it may be obtained by elective affinity.

Illustration. Pulverize a fragment of marble, and put a wine glass full into a pint retort. Pour on it about a gill of water. After it has soaked about a minute, pour in slowly half a wine glass of sulphuric acid, diluted with about five times as much water. The lime, forming the basis of the marble, will elect the sulphuric acid, and the carbonic acid will come over in a state of gas, and may be collected in any receiver placed on a shelf of the cistern.

Application. On this principle the carbonic acid for making acidulous waters, improperly called soda water, is obtained. But by what process nature disengages the vast quantity of this gas, which is required to charge the Saratoga and Ballston waters so highly, no one has hitherto suggested even a plausible conjecture.

Carbonic acid gas is absorbed by water, and in that state of combination gives the acid test.

Illustration. Pass some of the gas into a decanter of pure cold water and agitate it, as directed under simple substances. Pour into a wine glass of it some of the infusion of red cabbage, and it will become of a very light red colour. The infusion ought to be greenish when put in, by putting into it an extremely small quantity of an alkali before it is used, otherwise the change in colour made by the acidulous water will hardly be perceived.

Application. This proves the fixed air to be an acid gas. The taste of the water also indicates its acid quality. Carbonated waters, called soda waters, are prepared upon this principle. The quantity of carbonic acid gas, absorbed by the water, depends on the coldness of the water, and the force applied to compress the gas, while in contact with the water.. The waters sold under the name of soda waters, as prepared in most of our towns, contain both sulphurous acid and muriatic acid. Chalk is commonly used, which generally contains a little muriate of soda. This being decomposed furnishes muriatic acid; and it is impossible to avoid a little mixture of sulphurous acid, arising probably from a slight decomposition of some portion of the sulphuric acid, used in the process. To cleanse the gas from these deleterious impurities, Mr. Meigs, of Albany, prepares his gas and forces it once through his condenser, containing a small quantity of water, before he introduces the water for use. This small quantity of water readily absorbs all the muriatic acid and sulphurous acid, and wastes a little carbonic acid. This being drawn off and pure water added, the carbonated water is made very pure. Mr. M's machinery for performing this operation, and for increasing the condensing power, is very ingenious; for the use of which, I believe he has secured a patent right.

Carbonated water, containing but about thrice its bulk of the gas, used with the sirups commonly employed, makes an excellent table drink in hot weather. It may be prepared in a private family as follows: Procure a five or six gallon cask, made very strong with thick staves and good iron hoops. Fix into a stave near the bottom, a strong tin tube an inch in diameter, and a little longer than the cask, in an oblique position, so that the top will be about as high as the top of the cask. Fix in a common brass cock in another stave quite at the bottom, and another brass cock in the upper head. In the same head fit in strongly and perfectly air tight, a tunnel with a long nose, having a large notch or slit on one side of the beak of it. The nose must be so long that it will reach from the inside of the lower head to about two feet above the upper head. Now open the upper cock to let the air escape, and fill the cask by the tunnel with clean water, that is not very cold. Next make the gas, passing it in through the oblique tube, and the water will be forced out through the same tube at the same time ; and the upper end being high, the gas will be considerably condensed by the pressure.—After the water is all out, cork up the oblique tube, pour in, as quickly as possible, cold pure water, till the cask is one third full. After standing two or three hours, and being shaken a few times, the water may be drawn out at the lower cock, and will be a very pleasant drink.

Instead of a common glass retort, use a strong junk bottle, with a strong elbowed tin tube fitted to it, and fastened on with twine, which will reach into the barrel, through the oblique tube.

Carbonic acid gas is heavier than atmospheric air, extinguishes flame, and destroys life when breathed.

Illustration. Immerse a candle, suspended by a wire, in a tumbler containing atmospheric air, and let it be observed that it burns as it did in air not contained in the tumbler. Take out the candle and invert a glass cylinder, which is filled with carbonic acid gas, in the tumbler. The cylinder should be smaller than the tumbler, so that its mouth may enter the mouth of the tumbler ; and the mouth of the cylinder must be covered with wet paste-board, until it is brought directly over the tumbler. After holding the glass cylinder in this position about eight or ten seconds, the gas will have settled down into the tumbler. Now immerse the candle again, and it will be extinguished. The gas will remain in the tumbler, and still extinguish a candle for any length of time if a piece of dry paste-board be loosely laid over it, so as to prevent its being driven out by the motion of the air.

Fill a glass cylinder with carbonic acid gas, set it on the table with the mouth upwards, and put a live mouse into it. The mouse will appear convulsed for a moment and expire.

Application. This is the gas usually called choak-damps, by miners. Being heavier than atmospheric air, it settles down into wells and caverns, and often destroys the lives of miners. As it is absorbed by water, unless it is very rapidly produced, none will be found to remain in wells which contain water; but it is generally found in deep dry wells, which are dug in very compact earth or in rocks. In all such cases, a candle should be let down before the well is entered. But the gas may be found in wells containing water; for water will not generally absorb more than its bulk of the gas in twenty-four hours, and a larger quantity may be produced in that time, especially in limestone countries.

Carbonic acid gas may always be found, in a greater or less proportion, suspended in the atmosphere.

Illustration. Pour limpid lime water from one tumbler into another, letting it fall about twenty inches, for about a dozen times in succession, and the lime water will become milky, which is the test of the presence of carbonic acid.

Application. Carbonic acid is found to be excellent food for plants, when absorbed by fresh earth, by carbonaceous manure, &c. as before observed. Therefore its suspension in the atmosphere affords an inexhaustible fund of vegetable nutriment.

Carbonic acid gas is given out by animals at every respiration.

Illustration. Put some limpid lime water into a wine-glass and breathe in it through a tube extending to the bottom of the glass. After thus exciting a bubbling in the lime water five or six seconds, it will become milky.

Application. It was observed under oxygen, that the pure oxygen was given off from vegetables by the action of light; which oxygen is essential to the health and even to the existence of animals. Here we perceive, by this experiment, that animals in return give off carbonic acid, which is most important to the growth of vegetables. Therefore animals and vegetables ought to live near each other.

Carbon and hydrogen may be united, forming carburetted hydrogen gas, by decomposing water with charcoal.

Illustration. Collect some pieces of charcoal from an old coalpit bed, or from some other place, where the coal has been exposed to the weather several years, and become intimately combined with water. Dry it, pulverize it, and heat it in a gun-barrel, as directed in procuring oxygen from manganese. Collect it in the cistern, and put some into a gas-holder and burn it, as directed in burning hydrogen. It will burn with a blue flame, without giving much light.

Application. As in this case the charcoal decomposes the water which it held in combination, and a part of it unites to the hydrogen; so decaying or putrifying vegetables in swamps, &c. decompose water and form the same gas, which is generally called marsh miasmata. It appears too in the bottom of stagnant ponds, &c. which may be collected in bubbles by pressing upon the mulchy sediment.

Carburetted hydrogen gas will explode when inflamed with oxygen.

Illustration. Mix some of the gas in equal volumes in a bell-glass or tumbler. Pour it into a narrow mouthed bottle or decanter. Invert the bottle under the water of the cistern, holding the mouth four or five inches below the surface of the water, resting the side of the bottle against the edge of a shelf. Having wet a roll of paper in spirits of turpentine, light it and hold it close to the water over a funnel hole in the shelf, and let up the gas in small bubbles. When the bubbles come in contact with the blaze of the turpentine taper, they will explode, exhibiting the cracking of musquetry firing from under the water.

Application. A similar gas is sometimes generated in coal mines, which coming in contact with the oxygen of the air, often explodes when the workmen go into the pits with candles. But it is found, that if the candle is enclosed by fine wire gause, called Davy's safety lamp, the gas will not explode. If the instructor has such a net, the class will be highly gratified with its exhibition, which may be easily made in a large glass jar filled with the mixture of gases just mentioned. See M'Neven's Brande, p. 142.

Carbon and hydrogen may be united, forming a heavy carburetted hydrogen gas, called olifiant gas, by heating alcohol and sulphuric acid together.

Illustration. Put a gill of alcohol into a deep tubulated retort, pour upon it in a small steady stream about twice as much by measure of strong sulphuric acid. Put in the stopper and apply the candle to the retort, approaching it gradually. The alcohol at first becomes somewhat charred and turns black, soon afterwards the gas comes over. Let a little of the first escape, which consists of atmospheric air and ether. Collect the gas over water. If it contains considerable sulphurous acid it will generally disappear soon while standing over water; but lime water will entirely purify it, if necessary.

Mix it with oxygen, and explode it as directed with the light carburetted hydrogen. Also burn it pure in a stream, as directed in burning hydrogen gas, and it will give a very luminous blaze.

Fill a glass cylinder half full of this gas, and then fill the remainder with chlorine gas. Their volume will be diminished, water will ascend, and its surface will be covered with an oily pellicle.

Application. Both the formation of this gas, when the alcohol becomes charred, and its producing an oil when mixed with chlorine, present a curious exhibition of changes produced upon vegetable matter, while passing through different states of combination.

Carbon and hydrogen will unite, partly as in the light, and partly as in the heavy carburetted hydrogen gas, by distilling pit coal with a red heat. This produces the gas used for what is called the gas lights.

Illustration. Pulverize some pit coal, commonly called sea-coal, and heat it in a gun-barrel, as directed in using charcoal, and obtain the gas in the same manner, with the following exceptions.

Fit a piece of wood in the form of a half cylinder, so that it will fill one half of the gun-barrel from end to end. Set it in an oblique position with the empty side downwards, and in this position put in the pulverized coal, so as to fill it about one third of its length. Now put it into the fire with the same side downward, and after it is placed in the situation in which it is to remain, draw out the piece of wood, leaving the barrel but half filled. When the heat is raised the coal will swell and fill the barrel, which it would burst if filled at first. The gas will soon come over in abundance, and bring over with it great quantities of mineral tar and bitumen. It should stand over water several hours to let these substances subside. If it is received into the gas-holders of the cistern, the water must be drawn off, the cistern washed and filled with clean water, before it is used for other purposes. The gas may be exploded with oxygen, and burned in a stream, as directed with light carburetted hydrogen. The blaze will be less white and luminous than of the olifiant gas, and more so than of the carburetted hydrogen.

Application. This is the principle on which the gas for the gas lights is obtained. But the apparatus is so arranged as to obtain it very economically, and purify it without expense. The mineral pitch is preserved for useful purposes. In London seventy-six thousand lights are supported by this gas with 28 chaldrons of coal per day. See Gorham's Chemistry, p. 407, vol. 1. M'Neven's Brande, p. 141. Messrs. Taylors of England, have lately contrived a method for obtaining a gas for gas lights very economically from every kind of oil.

BORON.

Boron, combined with oxygen in the state of boracic acid, is united to a base of soda, forming borax, from which it may be obtained in solid scales by elective affinity.

Illustration. Dissolve common borax in about six times its bulk of hot water in a gallipot. Then pour into it about half its weight of sulphuric acid. After stirring it on pretty hot coals for five or six minutes, set it by to cool. A decomposition takes place, sulphate of soda is formed which remains in solution, and the boracic acid is disengaged and appears in solid shining scales. Pour off the liquid solution of sulphate of soda, and rince the scales several times in cold water. Every time wait for them to separate from the water, in which they can hardly be dissolved. When well washed they are nearly tasteless. Now dissolve some of the boracic acid scales in alcohol on an earthen plate and set the alcohol on fire with a lighted roll of paper, and as it burns the points and sides of the flame will be tinged with a beautiful green.

Application. This experiment exhibits one mineral acid in the solid state when pure. The salt, which this acid forms in combination with soda, is much used in brazing, under the name of borax, I believe it is always found in Asia.

NOMENCLATURE

OF METALLIC AND METALLOID BASES.

When a salt is composed of a base united with an acid in its highest state of acidification, the name of the acid ends in *ate*—if the acid is in the lowest state of acidification its name ends in *ite*. As saltpetre is composed of nitric acid and potash, it is called *nitrate* of potash—potash and nitrous acid would be called *nitrite* of potash.

Sometimes the state of the oxydation of the base is expressed by prefixing its degree to the name of the acid. As copperas is sulphuric acid combined with the *protoxyd* of iron, it would be *proto-sulphate* of iron. As blue vitriol is sulphuric acid combined with the *deutoxyd* of copper, it would be *deuto-sulphate* of copper.

When an acidifiable substance is united to a base without being acidified, it ends in *uret*. As sulphur and iron melted together form *sulphuret* of iron—sulphur and potash, *sulphuret* of potash. When the compounds are both acidifiable substances not metallic or in the state of gas, *uretted* is generally the termination. As *phosphuretted hydrogen gas*, *sulphuretted hydrogen gas*, *carburetted hydrogen gas*.

When two or more metals are combined, they are called *alloys*; unless one of the metals is mercury, when the mixture is called an *amalgam*. When a metal is combined with any substance, excepting another metal, it is said to be *mineralized* with it. This, however, is a term appertaining rather to mineralogy than to chemistry.

CLASS IV. METALLOIDS.

SECTION I. ALKALIES AND ALKALINE EARTHS.

Remark. It is now established, that these alkalies consist of peculiar bases, united to oxygen. These bases have some properties in common with metals ; but they differ so widely in other properties, particularly in their specific gravity, that they are denominated *metalloids* by Brande and some others. The oxygen may be separated from the bases by a very powerful galvanic battery, and some of them by other means. And though such experiments are brilliant and very amusing, they have no practical application to the purposes of life. They would be introduced here, however, as well calculated to illustrate principle, were they not attended with too much difficulty and expense for the course proposed in this work. See Gorham's Chemistry and M'Neven's Brande.

POTASH.

Potash may be obtained tolerably pure by abstracting the carbonic acid from pearlash by the aid of quick lime.

Illustration. Dissolve pearlash in about twice its weight of boiling water. Mix this with about as much newly slacked quick lime. Let this stand about a week corked closely in a bottle, occasionally shaking the mixture. At last let the lime settle to the bottom, and carefully pour off the supernatent liquid, which is the pure caustic potash in solution. But if it be wanted for immediate use, boil the mixture about an hour in an iron kettle, adding water enough to keep it in the state of a cream-like liquid, and the decomposition will be effected. If the potash is wanted in a crystallized state, evaporate the liquid very slowly, just keeping the steam rising from it, and obtain the crystals as directed in the introduction.

Application. Pearlash, the sub-carbonate of potash, is made while a high heat is applied. Consequently vegetable impurities and most substances contained in common potash are driven out. Now the carbonic acid being withdrawn also, the potash is left nearly pure and severely caustic.

Potash has a strong affinity for all acids, and forms with them neutral salts.

Illustration. Dissolve a small quantity of common potash in a wine glass of water. Prepare another wine glass of very diluted sulphuric acid. Pour into a third glass a little of the infusion of red cabbage. Now drop into the infusion a few drops of the potash, and it will become green, which is the alkaline test. Next, drop diluted sulphuric acid into it very cautiously, and it will become colourless; which proves that the acid and potash have combined chemically and formed the neutral salt, sulphate of potash. Add another drop of the acid, and it will become red; which proves that the acid is in excess. That is, the potash had taken up its definite proportion of the acid, before the last drop was added, and could receive no more; consequently the last drop of acid, being free, gives the red colour, which is the acid test. Now more potash may be added, precisely sufficient to take up the excess of acid, and it will again become colourless. Add a little more and it will become green. Thus it may be changed from red to green and back to red as often as the acid and alkali are alternately added in excess. Great care is required in making the salt perfectly neutral, so as to make the solution colourless.

N. B. This experiment may be performed with all acids and alkalies, of course the directions will not be repeated.

Application. When clothes are spotted with acids, if a solution of pearlash be made and the spots be wet with it immediately, before the texture is injured, the spots will disappear by the neutralization of the acid, and the clothes will not be injured. Caustic potash would injure the cloth ; but pearlash, being a sub-carbonate, is more mild, and will effect the object.

Potash has a strong affinity for all animal matter.

Illustration. Melt a little common potash in an iron ladle, then put into it small bits of fresh meat and woollen rags and boil them a short time. The rags and meat will be dissolved and soap will be formed.

Application. On this principle soap is made by boiling any animal substance with ley, which is a solution of potash. It requires very strong ley, or rather melted potash to convert rags and some other animal substances into soap. As potash readily becomes diliquescent, as shewn under simple substances, soap is always soft or in the state of an imperfect liquid when potash is used.

Potash will unite directly with sulphur, and form sulphuret of potash.

Illustration. Take some dry pearlash and half as much sulphur, mix them and rub them well together. Melt them together in a crucible covered with another crucible, as directed in making sulphuret of iron, excepting that it must be poured out when melted. It must also be corked up in a vial to prevent its diliquescing.

Application. Sulphuretted hydrogen gas may be made with this, as with the sulphuret of iron. It is also used in medicine, and was called liver of sulphur or hepas sulphuris.

Potash may be combined with nitric acid, and form nitrate of potash, called saltpetre.

Illustration. Fill a tumbler half full of diluted nitric acid, consisting of one part of nitric acid to six parts of water. Drop in pearlash, a little at a time, until it ceases to effervesce. This will be the nitrate of potash in solution. Now if it is wanted in the state of crystals, evaporate it as heretofore directed.

Application. Saltpetre is found in abundance in nature, combined with a little common salt; therefore it is never made in this way, excepting by way of experiment.

Nitrate of potash may be reduced to the nitrite of potash by heating it.

Illustration. Put two or three ounces of saltpetre in a gun-barrel, and put it into the fire. It will melt and boil rapidly at a low red heat. Oxygen gas will come over in considerable quantities.

After oxygen ceases to come over, pour out the contents of the barrel, which will be nitrite of potash.

Application. This is the easiest method of collecting oxygen; but it is not quite so pure as that which is collected from oxyd of manganese and red lead.

Potash may be combined with chlorine, or oxymuriatic acid, and form the oxymuriate of potash.

Illustration. Fill a two quart bladder with chlorine, or oxymuriatic acid gas. Fit to the stopcock of the bladder a small glass tube. Dissolve about an ounce of pearlash in a pint of water, and put it into a receiver. Immerse the end of the tube in the solution, and close the tubulature where it enters, with beeswax. Lay a light weight upon the bladder, which will press it gently, and turn the stop so as to let out a very minute stream of the gas, so small that the whole shall not run out in less time than an hour or two. Let the receiver be almost air-tight, leaving only a hole a little larger than a pin in the wax by the side of the tube, where it enters the receiver, for the carbonic acid to escape, which will be driven from its connexion with the pearlash. After the gas is all pressed out of the bladder, draw out the tube, close up the receiver, and place it in a cool dark cellar. After a day or two, crystals of oxymuriate of potash will be found deposited in the bottom of the receiver. Pour off the liquid, scrape out the crystals and drain them. They must then be dissolved in considerable hot water. Set it away to cool, and the crystals will be formed again, which may be drained, dried, and put up in a vial for use.

Application. This preparation will explain much of the doctrine of affinity, &c. to the operator; but so little of it can be performed while his class is present, that it is preferable to purchase this salt of those who manufacture it in the large way in Woulf's apparatus.

Oxymuriate of potash will communicate oxygen to some combustible substances by compression, sufficient to inflame them and to produce explosions.

Illustration. Scatter some thin shavings of phosphorus over the bottom of a broad iron mortar.—Sprinkle crystals of oxymuriate of potash among them. Now, putting a leathern glove upon the hand, rub the iron pestle smartly around among the shavings of phosphorus, and a succession of explosions will be made, resembling the irregular discharges of militia musquetry.

Application. These explosions are caused by the sudden conversion of two solids into the state of gas. Oxygen is combined in the salt in the solid state. Phosphorus is also a solid. By being closely compressed, they instantly become phosphorus acid gas.

To the same principle all explosive powders owe their powers. Gunpowder is essentially composed of about 75 per cent of nitrate of potash, 15 per cent of charcoal, and 10 per cent of sulphur.—These substances are finely pulverized separately, and then intimately mixed. The nitric acid of the nitrate of potash, on being inflamed, parts with so much of its oxygen as to be reduced to nitric oxyd gas, and part of it to nitrogen gas. In doing this, oxygen is furnished to the charcoal sufficient to convert it into carbonic acid gas, and to the sulphur to convert it into sulphurous acid gas. These solid constituents of gunpowder, springing suddenly into the state of these four gases, expand their volume to such a vast extent, as to produce a violent concussion upon the atmosphere, and to impel a leaden ball, or other opposing body, with great velocity.

The same principle may be further illustrated by finely pulverizing and rubbing well together three parts of dried saltpetre, two of well dried pearlash, and one of sulphur. Melt the mixture in an iron ladle, with a degree of heat a little below the red heat of iron; and immediately after melting, the mixture will explode with violence. Here the three solid substances spring into several gases on the same principle, as before explained.

SODA.

Remark. Soda has many properties in common with potash. It gives the alkaline test, is obtained pure in the same manner, unites with acids, animal matter, &c. But its affinity for the acids is more feeble, and it does not diliquesce by attracting vapours from the atmosphere. Combined with oils it forms hard soap, whereas potash always forms soft soap.

Soda may be combined with muriatic acid, and form common table salt, muriate of soda.

Illustration. Put muriatic acid in a tumbler, diluted with about six times its measure of water. Drop in carbonate of soda till effervescence ceases. Proceed in all respects as directed in making saltpetre. Pass some of the solution among the class, and they will recognize the table salt.

Application. This salt is found so abundant in nature, that it is never produced in this way, excepting for the purpose of shewing its constituents. The ocean abounds in it, the western salt springs, the mines of Poland, &c.

Common salt may be decomposed conveniently by potash, so as to afford soda to combine with oil, or for other uses.

Illustration. Make a strong solution of common potash, and heat it in a skillet. Put in about as much common salt by weight, as of the potash.—Soon after the salt has melted, put in about the same weight of tallow, or other oily substance. Let this mixture boil until it assumes a considerable consistence on the top. Now pour it upon a wide board, let it drain off at the edges and remain to dry, and it will become hard soap. In this experiment, the muriatic acid of the salt elects the potash, and the soda is left free. In that state, the soda unites with the tallow and forms hard soap, leaving the muriate of potash in a state of solution to drain off, or pour away.

Application. On this principle soap boilers make the common hard soap. The liquid muriate of potash they call waste-ley or dead-ley. The fine hard soap is made directly from the barilla or kelp, which is a rough sub-carbonate of soda made from the leached ashes of sea-weeds.

Soda may be combined with sulphuric acid and form Glauber's salts, sulphate of soda.

Illustration. Put some sulphuric acid into a tumbler, diluted with six times as much water. Drop in carbonate of soda, until effervescence ceases. Now pass some of the liquid in wine glasses and the members of the class will recognize the nauseous taste of Glauber's salts. It may be crystallized by slow evaporation in the usual way.

Application. This salt is produced for the shops at the manufactories of muriatic acid. For the sulphuric acid which is poured upon common salt to disengage the muriatic acid, combines with the soda of the salt, and forms sulphate of soda. After purifying it is sold to the druggists.

AMMONIA.

Remark. This substance is one of the compounds under Nitrogen. But it was referred to this place for a description of its properties, on account of its near relation to the fixed alkalies. This is usually called the volatile alkali.

Ammonia is obtained in the state of gas from sal ammoniac by elective affinity.

Illustration. Pulverize a table spoonful of sal ammoniac, (muriate of ammonia) and put the dry powder into a half pint retort. Put in with it about twice as much fine quicklime. Now mix them well by shaking the retort. Having luted on a pipe-bowl, with half an inch of the stem, upon the beak of the retort, as directed in obtaining muriatic acid gas and for the same reason; now immerse the beak in the mercurial trough, and apply the heat of a candle to the retort. The ammoniacal gas will immediately come over. Let it escape a little while, that the atmospheric air may be driven out. Now collect it as directed in collecting muriatic acid gas.

Application. Hartshorn vials may be prepared upon this principle. Put pulverized sal ammoniac and quicklime into a vial and cork it closely.— Whenever the scent of the ammonia is wanted, shake the mixture before pulling out the cork. The same effect will be produced by rubbing dry quicklime upon the surface of a piece of sal ammoniac, and applying it to the nose. In all these experiments, the muriatic acid of the muriate of ammonia elects the lime, and the ammonia is discharged; and ammonia when pure is in the state of gas.

Ammonia extinguishes flame after a momentary enlargement of it, and destroys life when breathed.

Illustration. Immerse a short piece of a burning candle in a small cylindric glass of the gas. The blaze will be enlarged a little for an instant and then be extinguished. Put a mouse into it and it will soon expire.

Application. Though the action of this gas, by stimulating the olfactory nerves, revives a fainting patient; yet it will destroy life if respired several times. If oxymuriatic acid is inhaled by accident, let some ammoniacal gas be instantly inhaled after it, and it will correct its destructive effects. The two gases probably form an imperfect oxymuriate of ammonia in the lungs. That this effect is produced I had an opportunity to demonstrate by most painful experience, while giving a course of lectures in the capitol, before the New-York state legislature.

Ammonia in the state of gas, will unite with muriatic acid gas, and with carbonic acid gas; and with the former produce the solid muriate, and with the latter the solid carbonate of ammonia.

Illustration. Fill two small glass cylinders half full of ammoniacal gas over mercury. Pass muriatic acid gas into one from a vial which is small enough to turn under the cylinder, and carbonic acid gas into the other. Both cylinders will be lined with thin layers of salt, and the mercury will ascend to fill the vacancy. On passing the cylinders among the class with tasting rods, they will recognize the sal ammoniac (muriate of ammonia) in one, and the salts of hartshorn (carbonate of ammonia) in the other. Lest some of the class should not recollect the taste of these salts, it will be best to pass around specimens of each with the cylinders.

Application. These salts are not manufactured in this manner for the shops. The muriate of ammonia is produced in nature. The carbonate of ammonia is manufactured by heating chalk, (carbonate of lime) and muriate of ammonia together. A double decomposition takes place; carbonate of ammonia and muriate of lime are formed.

The experiments described in this illustration exhibit the reduction of gases to the solid state as clearly as any experiment of the laboratory.

Ammonia may be combined with nitric acid, and nitrate of ammonia be formed.

Illustration. Put nitric acid into a tumbler diluted with about six times as much water. Drop into it coarsely pulverized carbonate of ammonia until effervescence ceases; or until pieces of the carbonate will fall to the bottom without effervescence. A solution of nitrate of ammonia will then be formed. If it be required in crystals, evaporate it slowly, until a drop spread on cold glass is instantly crystalized. Then set it by to cool, and crystals will form on the top. Pour out the liquid part and evaporate it more, and so on as before directed. If the dry salt is required, evaporate it with a degree of heat a little below boiling, until the salt is dry, without removing it from the fire.

Application. This salt is chiefly employed for the purpose of procuring the nitrous oxyd or exhilerating gas. It is much the best for that use, to dry the salt down without crystalizing. Or if it is first made in crystals, it ought to be melted and dried down in open plates, before it is used. But if it is dried with a degree of heat as high as the boiling point, considerable of the salt will be lost.

Ammonia is strongly absorbed by water, forming the liquid ammonia.

Illustration. Pour from a vial a little cold water under a glass cylinder of ammoniacal gas standing over mercury. It will rapidly absorb the gas, and the mercury will ascend to fill the vacancy.

Put newly slacked lime into a tubulated retort which had been previously luted into a receiver and set it in a suitable lead pot. Put in about two-thirds as much pulverized muriate of ammonia. Now put in water, about six times the weight (call a pint a pound) of the muriate of ammonia. The muriatic acid will elect the lime as before observed, and the ammonia will be discharged ; but it will immediately be arrested by the water, forming the *liquid ammonia*, called also *spirits of hartshorn* and *aqua ammonia.* But being combined with the newly formed muriate of lime and some lime water, it must be distilled over. Raise the heat moderately by applying the hand bellows to the coals in the lead pot ; at the same time surround the receiver with snow or cold water. Continue the process until the liquid, condensed in the receiver, is equal in measure to about one third of the water put in.

Application. The first experiment proves, that as water absorbs ammonia, which is the basis of many impure gasses that arise from putrid substances, falling rains cleanse the atmosphere by carrying such impure effluvia to the earth, where they serve to nourish vegetation. The last experiment is an exhibition of the method of preparing the *aqua ammoniae* of the shops.

Liquid ammonia will unite with sulphuretted hydrogen gas, and form the hydro-sulphuret of ammonia.

Illustration. Let a stream of sulphuretted hydrogen gas pass into a vial of liquid ammonia. The best method is to put the ammonia into a broad-mouthed vial, filling it about half full. Turn the vial in an oblique position and extend the beak of the retort to the bottom of it. Wet tow may be wound about the neck of the retort where it enters the mouth of the vial to prevent the escape of the gas ; or if a little does escape it is immaterial, for the class ought to become sufficiently acquainted with this gas to be able to detect it by the smell. Now pour some of the liquid into a solution of copperas and another of blue vitriol.

Application. This is the most universal test for the metals known to chemists. It precipitates all metallic solutions with such different colours, when applied as a test, that, with collateral tests, almost any metal may be detected. For many metals it is a perfect test.

Remark. All the other alkalies will form hydrosulphurets also. But ammonia forms the most delicate test and is generally used.

LIME.

Remarks. Lime is very abundant. It forms the basis of all lime rocks which are combined with carbonic acid, whether primitive, transition or secondary ; from those which receive a polish, called marble, to the roughest of the common lime stone. It is the basis of chalk, coral rocks and shells. Combined with sulphuric acid, it forms the vast plaster beds of Nova Scotia and our western districts. Combined with phosphoric acid, it forms the bones of animals.

When carbonate of lime is heated about as high as the white heat of iron, the carbonic acid is converted into a gas and passes off. This process is conducted in large kilns, where quicklime is manufactured.

Pure lime has a strong affinity for water, with which it will combine chemically and form a liquid solution of lime, called lime-water.

Illustration. Put a wine glass full of newly slacked lime into a quart tumbler, and fill it with water. After stirring it about a minute, let it stand fifteen or twenty minutes to settle. Now pour off the colourless liquid into a large vial for use.

Pour some of the lime water into a wine glass and test it by a few drops of the infusion of red cabbage. It will become green, which is the alkaline test ; proving that the water, though limpid, is chemically combined with lime.

Application. The strong affinity of quicklime for water renders it an excellent drying material. An enclosed portion of atmospheric air or of any other gas may be dried by standing over unslacked lime. Col. Gibbs greatly improved the strength of gun-powder by mixing it with quicklime and thereby effectually drying it. Vid. Amer. Jour. Science, vol. 1, p. 87.

Lime water strongly absorbs sulphuretted hydrogen gas, and forms the hydro-sulphuret of lime.

Illustration. Pass sulphuretted hydrogen gas into lime water, as directed with ammonia, and the hydrosulphuret will be formed.

Application. This forms a good test for metals, but not so delicate as the hydrosulphuret of ammonia. This experiment shewing the affinity of lime for sulphuretted hydrogen gas, demonstrates its utility in cleansing putrid sinks, &c. For sulphuretted hydrogen being the essential part of most of the nauceous effluvia, if absorbed by lime the most disagreeable nuisance will be removed. For the same reason lime-water is useful in cleansing offensive ulcers, &c.

Lime will combine with carbonic acid, and form carbonate of lime.

Illustration. Set a tumbler of carbonic acid gas on the table, covered with a piece of pasteboard. After filling a low small glass cup with limpid lime-water, remove the pasteboard and let it down into the tumbler. Now stir it two or three minutes with a rod, and it will absorb so much carbonic acid that part of the lime will be carbonated, and become milky. Now take out the cup and set it by a few minutes to settle. On carefully pouring off the liquid, fine carbonate of lime, which may properly be called fine chalk, will be left. This may be tested by its effervescing on pouring upon it a little diluted sulphuric acid.

Application. Thus we see from this experiment, that carbonic acid may be driven from limestone by heat, rendering it pure quicklime; and it may be absorbed from the atmosphere, re-united and form the carbonate again. Thus lime mortar in walls becomes solid like marble, on exposure to air. On this principle a bowl of lime-water set in a room and occasionally agitated, would absorb the carbonic acid gas when a large quantity had been produced by the breaths of a crowd.

Carbonate of lime is dissolved in carbonated water, and will be deposited when the carbonic acid is abstracted.

Illustration. Charge a gill of cold water with carbonic acid in a florence flask, and drop in as much fine pulverized marble as will lie on the point of a penknife, perhaps a quarter of a grain. Shake it up a few times and the marble will totally disappear, being all dissolved and chemically combined with the water. Now set the flask into the lead pot, and boil the water four or five minutes. Take it out, wipe it clean and set it by to cool. After it is cool the fine marble will appear again in the bottom of the flask. For the carbonic acid being driven out of the water by heat, the carbonate of lime is deposited.

Application. This experiment explains the manner in which the calcareous tufa, called the high rock, at Saratoga is formed, and numerous other similar deposites. The carbonate of lime is brought along chemically combined with the carbonated water, until it comes out to be exposed to the atmosphere. Then a part of the carbonic acid escapes, and a part of the lime is deposited. Probably the numerous deposites of this mineral were made by carbonated waters which have ceased to flow for ages. The most remarkable locality within my knowledge is that through which the canal is dug, a few miles east of the Onondaga Salt Springs.

Lime has a strong affinity for oily substances.

Illustration. Pour olive oil into a wine glass of lime water, and a white liquid soap will be formed, by the union of the oil and lime.

Application. Lime is used in connexion with potash, &c. by the soap-boilers. It absorbs oils feebly in the state of a carbonate. The leaves of a book are often spotted with candle grease, lamp oil, &c. These spots may be totally removed by finely pulverized chalk or marble. Let the leaf of a book be placed between two pieces of white paper, with pulverized chalk interposed on both sides of the spot. Then set a common smoothing iron upon it, sufficiently heated to melt the grease. As soon as it is melted, the chalk will absorb it.

Lime, when mixed with silex or alumine, renders the mixture very fusible.

Illustration. Put a little potter's clay into a crucible, and heat in the forge as high as the white heat of iron. Now pour it out upon a brick on the table, and the class will see that it is not melted.—Mix some of the same kind of clay intimately with about an equal quantity of pulverized marble or chalk, and heat it again as hot as before. Pour it out, and the whole mass will spread upon the brick in the state of melted cinder.

Application. On this principle potters reject all clay which contains lime. About Albany, and other places along the banks of the Hudson, there is an abundance of the finest clay; but it contains about fifteen per cent of carbonate of lime. This would be sufficient to cause a kiln of potter's ware to melt, and of course cannot be used. The carbonate of lime can always be detected by pouring on a few drops of diluted muriatic acid. Ever so small a proportion of the lime will cause an effervescence, and prove the mass to be clay-marl, unfit for pottery.

Lime will combine with muriatic acid, and form muriate of lime; which salt in solution will change to solid gypsum on adding sulphuric acid.

Illustration. Pour diluted muriatic acid into a tumbler, consisting of about six times as much water as acid. Drop in pulverized chalk or marble until effervescence ceases, and muriate of lime in solution will be formed; but it will be too dilute. Evaporate it down to about half the measure. Now pour out half a wine glass of it, and pour into it sulphuric acid; solid gypsum, sulphate of lime, will be instantly formed.

Application. Most of the hard waters, as they are called, contain muriate of lime, in solution.—From this experiment it appears, that muriate of lime may be decomposed, and other salts of lime formed, which are insoluble. Such salts adhere to the bottoms and sides of vessels, as tea-kettles, &c.

Lime will combine with oxymuriatic acid, and form the oxymuriate of lime.

Illustration. Let a stream of oxymuriatic acid pass into water, in which finely pulverized and recently slacked lime is suspended by continual agitation. In the large way, a dry powder of newly slacked lime is spread upon the floor of a leaden chamber, and the gas passed into the chamber, which is absorbed by the lime. Others, however, prefer passing the gas into hogsheads of water, in which the lime is suspended by agitation. For an experiment, it may be pressed from a bladder, as directed in making oxymuriate of potash. But the bladder may be held in the hands and the receiver shaken continually.

Application. This is the bleaching salt, now used at the great factories. The manner of applying the salt is described in treatises on bleaching. It would be too long an article to introduce here.

BARYTES.

Remark. Barytes possesses many properties in common with lime. It is found in the United States in the state of a sulphate, in considerable quantities. The most extensive locality perhaps yet discovered in the world, is that in Carlisle, Schoharie county, New-York. This is a fibrous varity, but differs widely in its external characters from the fibrous varieties from Europe. It is called Schoharite, from its local situation, being near the western bank of the Schoharie kill. This variety is an excellent flux for brazing, &c. Perhaps every variety is equally good; but this has been proved to be so by abundant trials. All the salts of barytes, excepting the sulphate, are most deadly poisons.

Carbonate of barytes may be obtained from the native sulphate, by exchanging acids with pearlash, the sub-carbonate of potash.

Illustration. Put into a gallipot, or florence flask, pulverized sulphate of barytes with about three times as much pearlash, and apply heat sufficient first to melt the pearlash and then to boil the mixture for about three hours. Water may be added from time to time. Now put in considerable water so as to make a very diluted solution. Let it stand awhile, and the carbonate of barytes, which is produced by this double decomposition, will settle to the bottom, and the sulphate of potash will remain in solution. Pour off the liquid and put in water again, and thus wash it two or three times, and it will be ready for use.

Application. Having obtained carbonate of barytes, it is in a situation to be readily brought into any other state. As it has a stronger affinity for nitric, muriatic or sulphuric acid, than it has for the carbonic, either of those salts may be formed in the common way. Or if it be kept at a white heat in a crucible about half an hour, the pure barytes will be obtained. This will combine with water like lime, and form the barytic water, an excellent test.

Barytes will combine with muriatic or nitric acid, and form a test for the presence of sulphuric acid.

Illustration. Put muriatic or nitric acid into a tumbler diluted with about six times as much water. Drop in the carbonate of barytes, until effervescence ceases.

Application. This forms a perfect test for sulphuric acid in any state of combination. But it is a most deadly poison.

STRONTIAN.

Remark. Strontian has lately been found by Professor Douglass and W. A. Bird, in great abundance on an island in Lake Erie, in the state of a sulphate. Its carbonate and other salts may be obtained as directed for the barytes. It is not poisonous.

The salts of strontian may be distinguished from those of barytes by the color of its flame when burned with alcohol.

Illustration. Dissolve a little of the muriate or nitrate of barytes and strontian in separate portion of alcohol. Drop a little of each into the burning wicks of separate candles. The barytic salt will burn with a yellow, the strontitic with deep red flame. The solutions may be held in the blaze in silver tea-spoons, and they will burn more elegantly.

Application. These two heavy minerals greatly resemble each other. They are both used for tests, and probably may both be useful as fluxes. They will both combine with sulphuretted hydrogen, forming hydro-sulphurets; and by heating with sulphur, form sulphurets like all other alkalies.

MAGNESIA.

Remarks. Magnesia forms one of the constituents of the soapstone or talcose rocks, of asbestos, and some other minerals. It is found pure, or merely combined with water, in connexion with soapstone and serpentine rocks at Hoboken, opposite to New-York. It is found in the state of a carbonate in the same range of soapstone or talcose rock on Staten Island. It is found in the state of of an efflorescent sulphate, (called Epsom salts) in great quantities six miles north of Troy, on the east bank of the Hudson; also in the same situation at Coeymans, on the west side of the Hudson. Near the latter place is a spring highly charged with it. But magnesia is generally obtained from sea-water, after it is separated from the common salt. It exists in the state of a muriate and sulphate in sea-water, from which it is obtained by mixing with it a solution of common pearlash. A double decomposition takes place; and while the sulphate of potash remains in solution, the carbonate of magnesia falls down. The carbonate of magnesia, thus obtained, is the white magnesia of the shops.

The carbonic acid may be driven from its connexion with the magnesia of the shops by caloric.

Illustration. Drop diluted sulphuric acid upon carbonate of magnesia of the shops and it will effervesce; that is a bubbling will be caused by the escape of carbonic acid in the state of gas. Put a little of the same carbonate of magnesia into a crucible and keep it about the white heat of iron fifteen minutes. Now, after it cools drop on it diluted sulphuric acid and it will not effervesce, because the carbonic acid is driven out. If a little of it be dissolved with water it will give the alkaline test with red cabbage much stronger than before heating.

Application. This is called the calcined magnesia; and is considered as a more efficient remedy in some diseases than the carbonate.

Magnesia will combine with sulphuric acid and form the Epsom salts.

Illustration. Put sulphuric acid into a tumbler, diluted with about six times as much water. Drop in carbonate of magnesia until effervescence ceases.

This will form Epsom salts in solution. Pass some of it around and the class will recognize the bitter taste of the Epsom salts.

Application. This salt is so abundant in nature, that it is never prepared in this way, excepting by way of experiment, or when a practising physician happens to be in want of this article of materia medica.

SECTION 2. EARTHS WHICH ARE NOT ALKALINE.

Remarks. It is conjectured from analogy, that these earths consist of peculiar bases united to oxygen. These imaginary bases may be called metalloids also. Some chemists, however, have placed silex among acidifiable substances not metallic, and denominate it silicon. Gorham has followed that arrangement, but Brande has not.

SILEX.

Silex may be obtained pure from its earthy compounds, by combining it with an alkali and then separating the alkali with an acid.

Illustration. Heat a gun-flint red hot and throw it into cold water in order to render it brittle. Pulverize it very fine and mix the powder with about five times its bulk of pearlash, melt the mixture and keep it in the state of fusion fifteen minutes. Now dissolve it in two or three times its bulk of water. Pour in diluted sulphuric acid, a little at a time, as long as it continues to cause a precipitation. After it stands a little while to settle, pour off the liquid part, and wash or rinse the precipitate in hot water several times until the water poured off is tasteless. This powder is pure silex.

Application. This substance is the basis, or rather the principal ingredient in gun-flints, rock crystal, carnelion, &c. It forms much the largest proportion of soils and rocks. It is soluble in fluoric acid, as shewn under fluorine, but in no other acid. Heat rock crystal red hot and plunge it into water, and then pulverize it, and it will be almost pure silex; for crystallized quartz consists almost entirely of pure silex and the water of crystallization.

From the experiment described under this illustration it appears, that silex is readily dissolved when heated with potash. On this principle glass is manufactured. A due proportion of potash and quartzose sand are heated together and fused into liquid glass. This substance is then blown, while it adheres to the end of a tube, into the various forms required.

Glass sometimes contains the oxyd of a metal, which may be tarnished by hydro-sulphuret of ammonia.

Illustration. Pour some hydro-sulphuret of ammonia into any vessel of flint glass, (which always contains red lead) and it will become dark coloured or cloudy within. At the same time pour some into a vessel of crown class, bottle glass, or on common window glass, and it will not be tarnished.

Application. False gems made in imitation of true ones are always coloured with the oxyd of a metal. Oxyd of cobalt colours a glass gem smalt blue—black oyxd of manganese, violet—oxyd of chrome, emerald green, &c. If any such imitation gem be put into the hydrosulphuret of ammonia it will soon become tarnished.

The most convenient method for detecting frauds of artists, practised with false gems, is the following: Let gems be divided into four classes, according to their hardness. 1. Diamonds. 2. The sapphire class. 3. The rock crystal class. 4. Glass imitation gems. When a gem is to be examined, look out a smooth face upon it with a magnifying glass. Apply to that face a point or angle of a quartz crystal and attempt to scratch it. If any scratch is made, attempt to scratch the quartz with the gem. If the quartz cannot be scratched by it, it is glass; if it can, it is quartz. Minerals of equal hardness will scratch each other; therefore quartz will scratch quartz, &c. If it cannot be scratched with a quartz crystal, it may be considered as belonging either to the sapphire or to the diamond class. In this class are included oriental ruby, oriental amathyst, oriental topaz, corundums, emery, &c. Select a large smooth grain of unground emery, and apply it to a face of the gem as before directed. If it can be scratched with emery, but with great difficulty and not by the quartz crystal, it may be considered as belonging to the sapphire class. But if it cannot possibly be scratched with emery, after the most careful trials with severe pressure, it is a diamond.

Common window glass is pervious to solar caloric; but nearly impervious to terrestrial caloric.

Illustration. Hold a pane of glass between the face and the sun, and remove it alternately several times, no difference can be perceived in the heat of the rays. Now hold it between the face and a hot iron or a large fire, and it will defend the face most effectually, until the glass becomes heated, and thereby becomes like other conductors of caloric.

Application. Persons setting in a room in the evening, who are pleased with the light of the cheerful fire, but wish to defend their heads and faces from the heat, may do this most effectually with glass screens.

ALUMINE.

The alum of commerce consists of alumine combined with sulphuric acid, and a little potash; from this salt the alumine may be precipitated by ammonia.

Illustration. Dissolve common alum in water. Pour into it liquid ammonia as long as the precipitation goes on, and add a little afterwards. Now pour off the liquid, and wash this precipitate several times in water. This will be the pure, or nearly pure, alumine.

Application. This is the basis of clay. Pure alumine was never discovered native until my pupil, Dr. Ebenezer Emmons, discovered it in the summer of 1819, in an iron mine in the town of Richmond, Mass. It consists of pure alumine, combined with water. Prof. Dewey, who first analyzed it, called it hydrate of alumine, which nearly resembles the wavelite, though it is essentially different. Dr. Torrey calls it Gibbsite, in honor of a well known and highly distinguished character.

Alumine, mixed with silex, forms the chief part of soils; which mixture, when moistened with water, will absorb ammonia, carbonic acid gas, carburetted hydrogen gas, and all other gases which are nutritious to growing vegetables.

Illustration. Prepare glass cylinders of these gases over mercury, and pass into them separately balls of moistened earth. Some portion of each gas will be absorbed, with more or less rapidity. Some of them must stand several hours.

Application. From this experiment it appears, that the more frequently the moist earth is presented to the atmosphere by frequent hoeing, harrowing or ploughing, the more of the nutritious gases will be absorbed from it. This absorption, while it enriches the soil, purifies the air and renders it better fitted for respiration. This experiment explains the cause of the superior fertility of soils in the vicinity of large towns, compared with similar soils in different situations. The various impurities generated in large towns, the vast quantities of carbonic acid gas given off in respiration, the carburetted hydrogen and carbonic acid gases from a multitude of chimneys, &c. so highly charge the atmosphere with gases which are favorable to the growth of vegetables, that the very winds become the farmers' manure carters.

Alumine attracts water powerfully, by which its bulk is much enlarged; and its bulk becomes greatly diminished by forcing out the water with caloric.

Illustration. Make small clay cakes and dry them in the sun. Now bring them before the class, and mark their dimensions upon a board. Heat them in a crucible to the white heat of iron. Cool them and apply them to the measure, and they will be found to be greatly diminished in size.

Application. On this principle Wedgewood constructed his pyrometer. Nail down two thirty inch rulers on a board, half an inch apart at one end and an inch apart at the other. Graduate one of the rulers with marked degrees. If the sun-dried cakes of clay would just enter the large end, after heating they would enter considerable farther. The distance to which they would enter indicated the degree of heat which had been applied to the crucible containing the clay cake and the metal or other substance to be fused.

On this principle some bricks burned at a kiln are smaller than others, though all were made in the same mould.

Alumine has a strong affinity for the alkalies, whether they are simple or in the state of salts.

Illustration. Suspend some common clay in water by first stirring it up, and then letting it settle until it is semi-transparent. Now pour it in excess into lime water and stir the mixture occasionally for ten or fifteen minutes. Let it stand and settle a while, then pour some of it into a wine glass containing an infusion of red cabbage, and it will not give the alkaline test, because the alumine has combined with all the lime, and precipitated it.

Lay a sun-dried clay cake obliquely across a crucible of such a length as to go entirely into the crucible, but not let it reach the bottom. Heat the crucible until the clay cake is about red hot. Then throw a handful of common salt, muriate of soda, into the crucible and raise the heat almost to the white heat of iron. On taking out the clay cake its surface will be found covered with a glazing, made up of the soda and alumine fused together.

Application. The affinity between lime and alumine has an useful application in forming plastering for walls, &c. The experiment of glazing the clay cake is an exhibition of the process adopted by potter-bakers for glazing their ware, by throwing salt into the kilns when the ware is burning.

CLASS V. METALS.[*]

Remarks. The specific gravity of all pure metals is above five. They all reflect light brilliantly, which reflection is called the metallic lustre. Most of them are found in the earth combined with oxygen or sulphur. All are capable of becoming sulphurets by heating with sulphur, as directed in preparing sulphuretted hydrogen gas. Metals may be combined or alloyed together, in which state their fusibility is increased.

All metals must be in the state of oxyds, before they can combine with acids and form salts.

Illustration. 1. Put a drop of mercury into a wine glass and pour muriatic acid upon it. Muriatic acid cannot be decomposed by any metal, and mercury cannot decompose the water which is combined with the muriatic acid. Consequently the mercury will not be oxydated, and of course cannot become the base of a salt in this experiment.

2. Put a drop of mercury into a wine glass and pour nitric acid upon it. Though the water, which is combined with the nitric acid, cannot be decomposed by mercury, nitric acid can. Consequently the mercury will be oxydated in successive atoms by successive atoms of nitric acid; which will be

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[*] Many experiments upon metals require so much time that they cannot be commenced and completed in the course of a lecture, or of one meeting of the class. Others are of a difficult or rather dangerous nature. These may be passed over in a short course of lectures, after giving very particular explanations of their principles, and shewing, as well as can be done conveniently without actually performing the experiments, the necessary manipulations. These are distinguished by an asterisk (*) prefixed to the illustration.

reduced thereby to nitrous acid, and rise up in a deep orange gas, as described under nitrogen. As fast as the successive atoms of mercury are oxydated, they unite with the nearest atoms of undecomposed nitric acid, and nitrate of mercury is formed.

3. Put a small quantity of iron filings into a wine glass, and pour muriatic acid upon it. Though the muriatic acid cannot be decomposed by the iron nor by any other metal, as before observed; the water which is combined with the muriatic acid is readily decomposed by the iron. That the iron is oxydated by the oxygen of the water, is manifest from the disengagement of hydrogen gas which arises out of the wine glass. The iron being thus oxydated, immediately unites with the muriatic acid and forms muriate of iron.

Remark. In the second and third experiments considerable effervescence appears in the wine glass. In the second, it is caused by the escape of the nitrous acid gas, (or rather nitric oxyd which becomes nitrous acid when it comes in contact with atmospheric air,) and in the third, by the escape of hydrogen.

Application. Metals may be thus oxydated by the decomposition of acids or of water, or they may have been previously oxydated by some other process. In some cases a metal is first oxydated by an acid which it can decompose, and then united to a different one by double decomposition. For example, in preparing muriate of mercury, the mercury is first combined with sulphuric acid, because it will decompose that acid and become oxydated. Then its oxyd is combined with muriatic acid, by heating the sulphate of mercury with the muriate of soda. This process of double decomposition will be particularly explained under mercury.

Several of the metals may be burned with a brilliant flame, in a current of oxygen gas.

Illustration. Make a hole in the side of a large piece of charcoal, and put into the hole some iron filings, iron wire, zinc shavings, lead shavings, &c. Having filled a gas-holder with oxygen, prepared with a tin tube, terminating in a pipestem, as described in the introduction; hold the charcoal in a suitable position for receiving the current of oxygen upon the metals. Let an assistant hold the flame of a candle between the metals and the pipe, until the current of oxygen drives the flame into the coal. Then remove the candle and continue the current of oxygen, enlarging or contracting it at pleasure by turning the stop. The metals will burn very brilliantly, each exhibiting its own peculiar flame.

Application. This experiment demonstrates the combustibility of metals; aud shows the necessity of adding to the words *acidifyable substances* in the title of the third class, the words *not metallic*. For all combustible substances are capable of uniting with oxygen, and do unite with it during the process of combustion.

A very intense heat for burning metals may be produced by a current of oxygen and hydrogen gases combined. This constitutes what is denominated Hare's compound blowpipe, or the American oxy-hydrogen blowpipe.

Illustration. Fit the ends of two tobacco pipestems together at right angles, by filing them with a a small three cornered file in the following manner. File the hydrogen pipe flat on one side at the end, and file a groove across the end at right angles with the flat side. File the oxygen pipe at the end so as to make a shoulder to fit against the flat side of the hydrogen pipe, and file it so deep as to leave but half of the hollow of the pipestem; which when the pipes are put together, will exactly coincide with the groove across the end of the hydrogen pipe.—Now bore two holes in a slip of a pine board in a direction to fit in the pipes firmly, with their ends meeting in a joint at right angles as before described; but they ought to meet three or four from the board. Fasten the board in an upright position to support the pipes steadily. Having filled one gas-holder with oxygen and another with hydrogen, with stop-cocks fitted in them as usual, attach two flexible tubes to the stop-cocks at one end, and to the pipestems at the other, so as to conduct the proper gas to its respective pipe. Now turn the stop of the hydrogen gas-holder and let out a very small stream and inflame it with a candle.—Then turn the stop of the oxygen gas-holder, and let out a stream of oxygen rather larger than that of the hydrogen. A small faint blaze will be produced, but its heat will be very intense. Having previously provided the different metals intended to be burned, now apply them. Small rods of iron, lead, copper, &c. and gold and silver leaf, will burn like tinder. A very thin file with a long wooden handle will burn beautifully.

Application. On this principle, and by using platina tubes, minerals can be fused which resist the strongest furnace heat.

Letters may be etched upon metals by converting *the surface where the strokes are to be etched or the interstices between them into oxyds.*

* Illustration. Dip a cold bright knife blade into melted white wax. On taking it out the wax will immediately harden upon it. Mark out the form of a letter or figure upon it, and scrape off all the wax excepting that which is intended to cover the letter. Rub the wax off clean with dry pearlash. Then immerse the knife blade in the nitric acid, and let it remain fifteen minutes. Now take it out, scrape off the wax which has the form of the letter, and wash the whole clean. The letter will have a smooth surface and appear elevated above the other part of the surface of the blade, which will appear clouded and rough.

Application. On this principle the etching upon razors, sword blades, &c. is performed. But the artists have various methods for preparing compositions for applying to the metals before the acid is applied. They generally make use of something for writing the letters, which will flow from the pen like ink. Then they surround the whole space to be acted upon, by an edging to confine the acid, and pour on the acid instead of immersing the metal in it.

SECTION 1. METALS WHICH ABSORB OXYGEN WITH SUCH FORCE AS TO DECOMPOSE WATER, WHEN HEATED TO REDNESS.

Illustration. The distinctive character of this section may be illustrated by heating an iron rod to a high red heat and plunging it into a narrow mouthed tin cup of water. The smell of hydrogen will immediately be perceptible at the mouth of the cup, proving the decomposition of water; and on taking out the rod it will be covered with scales of protoxid of iron.

IRON.

Remarks. Iron is distinguished in the arts by three general kinds: *Cast iron*, *wrought iron* and *steel*. Cast iron contains a proportion of carbon, and is of a brittle granulated structure. By melting cast iron and stirring it while in fusion, part of the carbon is burned out. Then by hammering or rolling, it becomes almost pure, fibrous and tough, and is then called wrought iron. After it is brought to the state of wrought iron, it may be converted into steel by heating in a confined place in contact with charcoal, with which it combines. It will then become hard on heating and plunging into cold water, and is more fusible.

Besides the cast iron and steel, iron enters into another state of combination with carbon, forming the plumbago or black lead, as it is called. This is considered as the true carburet of iron, consisting of 95 per cent of carbon with 5 of iron, according to Allen and Pepys.

Oxyds of iron form the basis of most colours in minerals and vegetables. Gorham quotes from Hauy this elegant and appropriate expression—"when nature takes the pencil, iron is the colouring she always uses."

Steel may be distinguished from iron by the action of an acid upon its carbon.

Illustration. Let fall one drop of nitric acid upon a piece of polished iron, and another upon a piece of polished steel. The acid on the iron will be limpid or whitish, that on the steel will become dark brown or black.

Application. It is often very convenient to have a more ready method for distinguishing between iron and steel than the usual method of trying its hardening quality. It is not necessary to polish the iron or steel to make the trial. If a small spot on a coarse bar of iron or steel be filed bright it will be sufficient.

Iron becomes oxydated on exposure to air and water; and the red oxyd, or iron rust, thus made, always contains some carbonate of iron in combination.

Illustration. Collect some red iron rust and pour muriatic acid upon it, and carbonic acid will escape. Or heat it in a gun-barrel, as in obtaining oxygen from manganese, and carbonic acid may be collected.

Application. Iron rust, prepared by exposing very fine iron filings to water and air, is often used in medicine as a tonic. But it is a mistake to call this oyxd of iron; as it is a mixture of oxyd of iron and carbonate of iron.

Pure red oxyd of iron may be obtained by driving out, with caloric, the acid from a salt of iron.

Illustration. Put some copperas, sulphate of iron, into an unglazed crucible, and heat it moderately until it becomes a dry white mass. Then put it into a crucible which will bear a high heat, and raise the heat until it becomes very red.

Application. Here the iron is left in the state of a protoxid, after the sulphuric acid is driven off in the state of gas. Sulphuric acid was at first obtained by heating copperas in earthen retorts, and bringing over the acid. Copperas being called green vitriol, this acid was called vitriolic acid ; and by some the oil of vitriol, on account of its flowing like oil.

Sulphate of iron, (copperas,) *is formed by the chemical combination of iron and sulphuric acid.*

Illustration. Put diluted sulphuric acid into a florence flask, consisting of about five times as much water as acid. Apply a very little heat, so as rather to warm than heat the acid. Drop in iron filings until they will fall to the bottom quietly.—Pour off the limpid liquid into earthen plates. This is copperas in solution ; and by a slow evaporation it may be crystallized.

Application. On this principle the copperas of commerce is manufactured ; but it requires considerable experience to enable a manufacturer to perform the operation economically.

Iron will combine directly with sulphur by the agency of caloric, and form sulphuret of iron.

Illustration. Perform this experiment as directed in preparing sulphuretted hydrogen gas.

Application. Vast quantities of sulphuret of iron are found in the earth ; but these substances seem to be more perfectly united than they can be by art. The native sulphuret is never used for composing sulphuretted hydrogen.

Sulphur and iron, when in combination, seem to be strongly predisposed to combine with oxygen. On this principle the oxygen is taken from an enclosed portion of atmospheric air, as directed under nitrogen. Lemery produced artificial volcanoes, by ramming with force into a large pot, a paste, made of 100 lb. of iron filings, intimately mixed with 100 lb. of pulverized sulphur, and just water enough to make a dense paste. This pot is then buried to a considerable depth in the earth, and between ten and twenty hours afterwards it bursts out and burns with great force. I do not know that this experiment was ever repeated in America. It is said that no effect can be produced without a very large quantity of the mixture.

Though iron is mineralized with sulphur, oxygen and carbonic acid, it does not enter into many alloys. The principal alloy of iron known in the arts, is that of the sheet tin.

MANGANESE.

The peroxid of manganese (usually called the black oxid) *readily gives off its highest portion of oxygen on being subjected to the red heat of iron.*

Illustration. Produce oxygen from it as directed under oxygen.

Application. On this principle the manganese, as found in Trainer's mines at Bennington, and other places, is very useful for converting muriatic acid into chlorine for making the bleaching liquor, as explained under chlorine.

The peroxid of manganese is reduced to the protoxid, and oxygen given off, by the application of an acid which combines with the protoxid only.

Illustration. Pulverize some manganese very finely, and put it into a retort. Pour on it just enough strong sulphuric acid to moisten it, or moderately to wet it. Set the retort into the lead pot, and raise the heat, but not to a degree by any means sufficient to drive out the oxygen in the usual way, and oxygen gas will soon come over.

Application. In this experiment the sulphuric acid, on being heated in contact with the manganese, combines with the protoxid, forming sulphate of manganese, and presses out the oxygen above that proportion. On this principle oxygen is furnished to the muriatic acid in the production of chlorine, as described under chlorine. Red lead also being in too high a state of oxydation for the base of the sulphate of lead, oxygen is furnished to the muriatic acid in the red lead process for making liquid chlorine. In both cases, the oxygen is furnished to the muriatic acid at the instant of its disengagement from the soda of the table salt.

TIN.

Tin is not oxydated at the common temperature.

Illustration. Wet a piece of tin foil and a case knife blade and put them by, under the cistern or elsewhere in a damp place. The next day shew them to the class—the knife blade will be covered with rust, (or oxyd of iron and carbonate of iron) but the surface of the tin will not be affected by oxygen.

Application. On account of this property of tin, iron plates are covered with tin, forming the tin-plate ware. Lightning rods are tipped with tin to prevent the points from rusting. Copper vessels are tinned inside for the same reason.

Tin is oxydated, when heated so as to be brought to the state of fusion.

Illustration. Put some tin in an iron ladle, and heat it no higher than merely to melt it. The surface will immediately absorb oxygen from the atmosphere sufficient to form the *protoxid of tin*, called the yellow oxyd. This may be scraped off with an iron poker, when another similar pellicle will be formed; and the succession may be continued until the whole mass is a yellow oxyd.

If the protoxid of tin is put into a crucible, heated to redness, and continually stirred with an iron rod for some time, it will absorb another definite proportion of oxygen. It then becomes the *peroxid of tin*, called the white oxyd, or putty of tin.

Application. The white oxyd of tin is an excellent powder for sharpening edge tools, as knives, razors, &c. Also for polishing burnishers, glass lenses, &c. When melted with glass it forms the white enamel used for clock and watch faces, &c.

Tin combines with mercury at the common temperature; and at the time of its amalgamation with mercury will adhere to glass.

Illustration. Put a drop of mercury into a wine glass, and drop into it small pieces of tin foil, which will become liquified and unite with the mercury. Continue these additions until the amalgam contains about half as much tin as mercury. Next spread a small piece of tin foil very evenly on the face of a smoothing iron or a piece of polished marble. Pour the amalgam upon it and rub it over the tin foil with the finger for about two minutes. Now press upon it a piece of dry clean glass. Press it down with such force as to press out all the uncombined mercury. Lay a weight upon the glass and leave it half an hour; when it may be taken up, and will be found to be a mirror.

Application. All looking glasses are made in this way. In the large way a marble slab is placed in an inclined position, so that the excess of mercury runs off and is saved for the next, &c.

Tin will form an imperfect alloy with iron.

Illustration. Prepare a very thin slip of iron and scour it bright, dipping it several times, while scouring it, in very dilute sulphuric acid. Bend one end of it, so that it will fit the inside of the bottom of a crucible. Melt some tin in the crucible, and dip the bent end of the slip of iron into it. The tin will combine with the surface of the iron, and, if it is very thin, it will penetrate entirely through it.

Application. On this principle the sheet tin is manufactured. We may often find sheets of tin, which, on cutting them across, appear to be alloyed entirely through with the tin; and may be soldered after considerable is worn from the surface.

Tin will adhere to the surface of copper, if perfectly cleaned and heated.

*Illustration. Prepare a slip of copper by scraping it well with a knife and rubbing it over with sal ammoniac, (muriate of ammonia.) Now heat the copper over clean coals, which do not emit smoke; at the same time rubbing it over with rosin. While hot and thus cleaned with the sal ammoniac and rosin, rub tin upon it in the solid state, which, being melted by the heat of the copper will adhere to it, giving it a silvery white surface.

Application. By a similar process copper kettles and other copper vessels are tinned inside.—When the tin has worn off, any ingenious housekeeper might repair it in this way.

Tin dissolved in nitro-muriatic acid (aqua regia) *forms the muriate of tin; used for giving cochineal the scarlet colour.*

*Illustration. Prepare the nitro-muriatic acid by mixing one part of muriatic acid with two of nitric acid, and put a very small quantity into a florence flask. Drop tin into it by small quantities, that it may not become too hot by the rapid union of the tin and acid. After the acid is saturated, dissolve some of it in water.

Application. Dissolve in water in a wine glass a single cochineal insect of the shops, and drop in a little muriate of tin; and it will become of a bright scarlet.

It may be made by dissolving the tin in strong muriatic acid, and then exposing it some time to the atmosphere. When muriatic acid is used, the tin takes the lowest portion of oxygen. It is then the *proto-muriate of tin.* When the nitro-muriatic acid is used, the tin takes the highest portion of oxygen. It is then the *per-muriate of tin.* But if the proto-muriate of tin is exposed to the atmospheric air, the tin takes another portion of oxygen, becoming the per-oxid; and the salt is of course the per-muriate of tin, which is used by dyers.

ZINC.

Zinc forms a white oxid, very light and flocculent, on being melted and boiled in contact with atmospheric air.

Illustration. Put into a crucible two or three ounces of zinc. Raise the heat so as to melt it, and then boil it a short time. Now raise the heat still higher and stir it with a rod. Flocculent flakes, of the white oxyd will begin to fly out of the crucible. Take the crucible out of the fire and hold it in fair view of the class, continually stirring it.—The room will now be filled with the oxyd, which is carried about by the air like fine down.

Application. This is the substance which was formerly called *white nothing*, (nihil album,) *philosopher's wool* and *pompholix*. In medicine it was called flowers of zinc. When intended for medical use it is collected from the sides of the crucible, put into water, and stirred up a while; then suffered to settle. Afterwards the water is poured off, the oxyd is dried and put up for use.

Fine filings of zinc may be oxydated and inflamed with explosion, by mixing it with oxymuriate of potash and striking the mixture with a hammer on an anvil.

Zinc combines with sulphuric acid and forms sulphate of zinc, called white vitriol.

Illustration. Pour diluted sulphuric acid upon zinc, leaving the zinc in excess. After the action ceases, pour off the clear liquid, which is the white vitriol in solution. If this be evaporated slowly, crystals will be formed.

Application. By a similar process the white vitriol of the shops is manufactured.

The native sulphuret of zinc is found in South-Hampton mines and other parts of N. England, and the red oxid is found in New Jersey.

SECTION 2. METALS WHICH ABSORB OXYGEN, BUT NOT WITH SUFFICIENT FORCE TO DECOMPOSE WATER.

(May become acids capable of combining with salifiable bases.)

Remark. Five of the metals may themselves become acids, and unite with other metals and with metalloids; not as alloys, but as acids forming salts with them. Two of these are very rare metals.—Columbium and Tungsten. Molybdena is a difficult mineral to manage. Chrome has been found in considerable quantities in Maryland, and some in other places. But one metal in this subdivision of the second section, however, will be introduced here for experiments.

ARSENIC.

Remarks. Arseniate of cobalt is not uncommon in the hornblende rocks of this country. It is found in Hungary, &c. in the state of a red sulphuret, called *realgar;* and in the state of a yellow sulphuret, called *orpiment.* Numerous combinations of this metal in the state of arsenious and arsenic acids, are given in the large works on chemistry. But I shall confine my experiments to those which may be required for detecting its presence as a poison. It is a deadly poison in the state of *arsenious acid*, which is the solid substance commonly called the white oxid of arsenic.

Arsenious acid, when thrown upon ignited charcoal, gives off the scent of garlic.

Illustration. Take some burning coals upon a shovel,and sprinkle the common arsenic of the shops upon it. White fumes will arise, which give the smell of garlic.

Application. After all the various and complicated methods proposed by chemists, this is the best method known for detecting the presence of arsenic. The method proposed for subliming it in a glass tube is a sure one, if accurately conducted.

But after obtaining metallic arsenic by this process, still the smell is resorted to as its best test. So nothing is gained; and the difficulty of conducting this process in all places, and in the bustle which usually attends an enquiry after the death of one suspected to have been poisoned, is much against it.

It is said that other substances smell like garlic. So other substances may be sublimed. Mercury may be sublimed, so as to deceive the inexperienced. But there is no known substance in the form of a white powder, which gives the odour of garlic when thrown on hot coals, but arsenic. And unless the arsenic is so obtained as to be capable of being thus presented to hot coals, it cannot be examined in any other way.

I hope no student, who takes lessons from this little work, will place much confidence in any of those investigations made by physicians in regard to poisons found in the stomachs of dead bodies. Put an ounce of arsenic into the well filled stomach of a dog, and set ten of the best physicians in Europe or America to search for it; and unless they are practical chemists of considerable experience, they will not be able to detect it to the satisfaction of an honest and discriminating mind. But let the busy tongues of two or three sage matrons set up the cry of arsenic, and twenty wise sons of Aesculapius will find any quantity of it in a stomach where nothing but the mother's milk had ever passed the subject's lips.

Many an honest man has suffered death, and many an innocent family has been ruined, through the affected wisdom of physicians, and scientific quackery of the bench and bar.

(Not capable of becoming acids.)

COPPER.

Remarks. Copper is found native in many places. It is also pretty common in the state of a sulphuret and a carbonate. Copper alloyed with from 12 to 18 per cent of zinc forms *brass*. When the proportion of copper is larger it forms *pinchbeck*. Six parts of copper, two of tin and one of arsenic form *speculum metal*. Three parts of copper with one of tin form *bell metal*; and for little shrill sleigh-bells, &c. a little zinc is added. Copper and tin form *bronze* also, consisting of ten parts copper to one of tin.

Copper long exposed to moisture in a damp place becomes a green carbonate at the surface.

Illustration. Scrape off the green crust from a piece of copper and pour muriatic acid upon it, and it will effervesce by the escape of carbonic acid. Pure copper will not effervesce, which may be shown also.

Application. All copper and brass utensils should be defended from moisture by tinning or by careful cleaning; for the carbonate of copper is very injurious if taken into the stomach.

Copper combines with sulphuric acid and forms sulphate of copper, called blue vitriol or Roman vitriol.

Illustration. Boil copper filings in sulphuric acid, and the salt will be formed in the liquid state. This may be evaporated in the usual way.

Application. On this principle the blue vitriol of the shops is made; but not by a similar operation. The native sulphuret is heated and exposed to air and moisture, and thereby the peroxid is obtained. Then the salt is readily formed by pouring sulphuric acid upon it.

Copper has a strong affinity for ammonia, with which it will combine when in the state of salts or otherwise, and form various coloured compounds.

Illustration. Rub together in a mortar about equal bulks of sulphate of copper and carbonate of ammonia. A purple compound will be formed.

Application. This is the ammoniuret of copper used in medicine.

Copper combines with arsenious acid, and forms Scheele's green.

Illustration. This may be effected by a double decomposition. Form arseniate of potash by dissolving pearlash in water and heating it, then by dropping in common arsenic till action ceases. Dissolve sulphate of copper in hot water also. Pour the solution of sulphate of copper into the arseniate of potash till action ceases. Arseniate of copper and sulphate of potash will be formed. The arseniate of copper will precipitate and the sulphate of potash will remain in the liquid state. Pour off the liquid, and wash the precipitate several times. This will be the true Scheele's green.

Application. So much reliance is placed on this process as a test for arsenic, that every student in chemistry ought to be well acquainted with this colour.

ANTIMONY.

Remark. Antimony sold at the shops is in the state of a sulphuret generally.

Sulphuret of antimony will decompose water and form sulphuretted hydrogen gas.

Illustration. Pulverize the common sulphuret of antimony, and put it into a retort. Pour in water and dilute muriatic acid, apply heat and collect the gas, as directed under sulphuretted hydrogen gas.

Application. When we wish for a test in haste, it is often a convenience to apply the sulphuret of antimony, without the trouble of preparing the sulphuret of iron.

Sulphuret of antimony may be reduced to the state of the protoxid of antimony by heating with salt-petre and sulphuric acid.

* Illustration. Pulverize very finely equal parts by weight of sulphuret of antimony and salt-petre. After pulverizing, mix the two powders very intimately. Throw the mixture, all at once, into a crucible previously heated to redness, or rather higher. Deflagration will immediately take place, during which oxygen will be given off by the salt petre to the sulphur and convert chief of it into sulphurous acid, and to the antimony and convert most of it into an oxid. Now take off the crucible, let it cool, select all the reddish part of its contents and reject the rest. This is what is called in medicine *crocus of antimony*, or sometimes the metallic antimony; but it is not entirely separated from the sulphur.

Now mix this crorcus of antimony with about twice its weight of sulphuric acid in a gallipot or tea-cup. After mixing and remaining a little while, put it into a clean iron ladle and boil it down to a perfectly dry mass, frequently stirring it with an iron rod. This dry powder, when well washed, is the true protoxid of antimony.

Application. When antimony is brought to the state of an oxyd, it is in a convenient state for applying to various uses. It may easily be prepared for alloying with lead for the manufacture of printing types, &c.

Oxyd of antimony will combine with tartaric acid, and form the tartrate of antimony, called tartar-emetic.

*Illustration. Dissolve some supertartrate of potash (to be described under vegetable acids) in water, and put into it an equal weight of dry oxyd of antimony. Pour this mixture into a clean iron ladle, and boil it about fifteen minutes. Let it stand about a minute to settle any impurities, and then pour the liquid into any clean vessel to set by to crystallize. Or it may be cleaner to strain it through paper. After it cools and stands a while crystals of tartrate of antimony will be formed. The supernatant liquid may be poured off and evaporated a little, and set away to crystallize again. These crystals may be washed and put up for use.

Application. This is the important medicine so long in use, under the name, tartar-emetic. It is rendered more pleasant, by dissolving the crystals in boiling water, equal to about fifty times their weight. Then adding about a third more good wine than to equal the quantity of boiling water.

BISMUTH.

Bismuth combines with nitric acid, and forms nitrate of bismuth; the most delicate sympathetic ink.

Illustration. Whittle off a little bismuth into a wine glass. Drop in a little common nitric acid diluted with half as much water. Violent action will commence; when it ceases the nitrate will be found in the liquid state.

Dip a clean pen into it and write as with ink. Hold the paper near a fire, but not so near as to heat it, the letters will become invisible. Having shewn the paper to the class without any visible letters, now dip it into water and on taking it out the letters will become visible and appear as if written with pale ink.

Application. If a letter be written on ordinary subjects with ink, sentiments of a more delicate nature, expressive of sympathies which it is desirable to conceal from prying post-office clerks, &c. may be expressed in this liquid between the ink lines. The confidential correspondent has only to dip the letter in water before he may catch the fugitive sigh and feast his fervid imagination on the half-told assurances. But the writing will soon disappear, and leave not a vestige to prove a forgotten promise.

Water precipitates oxyd of bismuth from liquid nitrate of bismuth.

Illustration. Pour into the liquid nitrate of bismuth, prepared as in the last experiment, eight or ten times its bulk of water, and the white oxyd will be precipitated in a fine powder.

Application. This white oxyd, after being washed and dried, is put up for medical use. It is said to be an excellent tonic. It forms the basis of the most delicate face paints, or pigments for other uses. But it is so readily tarnished by sulphuretted hydrogen, that a painted face, where it has been applied, will become tawney at the approach of a small quantity of that gas. Consequently those who wear painted faces have two good reasons for retreating from the attack of nauseous scents.

Remark. The other five metals belonging to this division of the second section, need not be introduced for experiments in the course proposed. Instructors who think proper to experiment upon them, are referred to M'Neven's Brande, Silliman's Henry, Gorham's Chemistry, and Accum's Chemistry.

SECTION III. METALS WHICH DO NOT RECEIVE OXYGEN, EXCEPTING FROM STRONG ACIDS.

GOLD.

Gold may be dissolved by nitro-muriatic and by oxy-muriatic acids, and by no other acid.

Illustration. Put a little muriatic acid into a wine-glass, and twice as much nitric acid in another wine-glass. Drop into each a small piece of gold leaf, and neither of the pieces will be dissolved. Now pour the contents of one glass into the other, and both pieces of gold will be immediately dissolved.

Application. This mixture is the *aqua regia* of old authors. The new compound formed is muriate of gold; but it seems that gold requires the joint action of the two acids, the nitric acid affording oxygen for oxydating the gold, and then the muriatic acid unites with it.

Iron, silver, and copper may be covered with a thin coat of gold, which is called gilding.

*Illustration. Pour into a saturated solution of muriate of gold (that is, where there is no excess of acid) about twice as much sulphuric ether. Now brush upon a clean polished surface of iron or steel some of this liquid. The ether will soon evaporate and leave the gold covering the surface.

To gild silver or copper, heat gold and mercury together in a crucible, one part of gold to about eight of mercury, until they are completely alloyed; then throw the hot alloy into cold water.—Having wet the silver or copper with diluted nitric acid, brush on the alloy with a fine brush (a wire brush is best) as uniformly as possible. Then drive off the mercury with heat, placing the gilded metal over hot coals. Afterwards the surface must be polished with a burnisher. The only objection made to this method by artists is, that it is very difficult to lay on the alloy evenly. But old artists learn to brush over the bare spots while it is heating, being careful to avoid inhaling the mercurial fumes.

Application. This method of gilding iron is undoubtedly very perfect; but it is desirable that some better method for gilding the other metals should be devised. Most substances to be gilded may be conveniently covered with gold leaf. Gold is so very ductile, that the leaves are made very thin. It is said that about a pound of gold may be hammered out between beater's skins so very thin, as to furnish enough to gild a wire of sufficient length to surround the earth.

Adulterations of gold coin may be detected, without an analysis, by taking the specific gravity.

Illustration. Take the specific gravity of a piece of gold coin, according to the directions given in the introduction. If its specific gravity is 17.157, it is lawful coin.

Application. There is no metal so heavy as gold, excepting platina. And such is the value of platina, that there is no danger of its being alloyed with that metal. Standard gold coin is an alloy of one of copper to eleven of gold, in order to make the coin harder, that it may wear the better. The specific gravity of perfectly pure gold is 19.3. Copper, silver, and most other metals, which are alloyed with gold, may be easily separated from gold by nitric acid. For if the alloy be in fine filings, the nitric acid will dissolve the other metals, and leave the gold in a black powder. This powder may be separated and melted down into a pure mass.—But the most common method adopted by artists is, to melt the alloy with sulphuret of antimony.—The other metals become sulphurets, and the gold will unite with the antimony and fall to the bottom of the crucible. After cooling it may be separated. Now melt the alloy of gold and antimony, boil it at a white heat, and the antimony will become volatilized and fly off.

SILVER.

Silver coin is alloyed with copper, as 12⅓ *to* 1*; from which alloy silver may be obtained pure, by forming a nitrate of it, and then precipitating it by solid metallic copper.*

*Illustration. Put some nitric acid into a wine glass diluted with an equal bulk of water. Drop into it a six-cent piece, and let it remain until action ceases. Now take out the undissolved silver, and put in a plate of perfectly clean bright copper. The silver will be precipitated after a short time. Wash the powder several times; and put a little liquid ammonia into the water for the first washings. Now melt down the powder into a solid mass, which will be pure silver.

Application. It is very convenient to have a ready method for obtaining pure silver from coin when it is wanted for a particular purpose. But silver is harder and will wear longer if it contains a little copper. Ever so small a quantity of copper, however, in a finger ring or in any jewelry, which comes in contact with the skin, will tarnish.

Silver will combine with nitric acid and form the nitrate of silver, called lunar caustic, or lapis infernalis.

Illustration. Put nitric acid into a wine glass diluted as before. Drop in a piece of pure silver, and let it remain till action ceases. Take out the remainder of the silver. Evaporate the solution to a solid salt.

Application. This salt is used in medicine, and for a test of the presence of muriatic acid in mineral waters, &c. An *indelible ink* is also made, by dissolving it in pure water and then adding a little vinegar, also adding a little gum-arabic to give it consistency. If a piece of cotton or linen be dipped into a weak solution of pearlash, and then dried under a moderately heated smoothing iron; it may be written on with a clean pen dipped in this solution, and the writing will never wash out. Those who do not wish to take the trouble to make the lunar caustic may always find it at every druggist's shop.

Copper may be coated with silver, if rubbed with it when in the state of a powder combined with some of the salts.

*Illustration. Make a powder as follows: Take a few grains of silver in powder, as precipitated by copper in the first experiment, after it is washed and before melting—about an equal weight of alum, or a little more—six times as much table salt—also six times as much tartrate of potash. Pulverize all these articles and rub them well together. Rub the clean bright surface of a piece of copper with this powder and it will be silvered.

Application. Though this silvering is not very durable, it will defend the surface of copper from tarnishing while it lasts; and it may be easily renewed. Plating copper is much preferable. This is done by brazing on a thin bar of silver upon a thick bar of copper. Then both are rolled out into the proper thickness for use.

Nitrate of silver heated with alcohol and an additional portion of nitric acid, may be formed into an explosive or fulminating powder.

*Illustration. Pulverize a very few grains of lunar caustic of the shops. Put it into a florence flask, and add about five times as much alcohol and about five times as much strong nitric acid. If a pretty violent effervescence does not commence soon, apply the heat of a candle. As soon as it does commence remove the candle. As soon as a thick white precipitate commences, the effervescence may be regulated by occasionally pouring in a little pure water. After the action has ceased, let it stand and settle a short time; then pour off the supernatant liquid and wash the powder several times in pure water. Spread it on paper and let it dry and drain a while. Now put a grain of it on the blade of a case knife and hold it over a candle. As soon as the knife is a little heated it will explode. It will also explode violently by compression or friction.

Application. This is an interesting illustration of the wonderful force exerted when solids are suddenly converted into gases. But this preparation ought not to be made before a class; neither ought it to be exhibited in the course proposed here. I give the description of Mr. Silliman's method, for the amusement of those who have leisure to attend to it in a private office. It is the most powerful and the most dangerous of all known fulminating substances.

PLATINA.

Remarks. It will be very difficult to experiment much upon platina in the proposed course. It being the hardest and most infusible of all metals, it is polished and used as a concave reflector in the most powerful telescopes, where glass would melt or break. For crucibles and other uses it is employed in the laboratory. It has not been much used in the arts, on account of its scarcity.

Platina may be dissolved in nitro-muriatic acid; and will then form muriate of platina, which is a test for potash.

*Illustration. Put a grain or two of platina into a florence flask and pour in a small quantity of nitro-muriatic acid and apply a little heat. It will dissolve very slowly; but in a few days muriate of platina will be formed. Dissolve a little muriate of soda (common salt) in a wine glass, and a little pearlash in another. Put a few drops of the muriate of platina into each; and it will produce no effect on the solution of muriate of soda, but will give a yellow precipitate from the solution of pearlash.

Application. It is often a convenience to be able to distinguish potash from soda, without going the round of evaporation to dryness and then waiting to see whether it will diliquesce or effervesce.

The alloys of platina, Palladium, Osmium, Rhodium and Iridium, are to be seen in the separate state among rare collections only.

SECTION 4. METALS WHICH ABSORB OXYGEN AT LIMITED TEMPERATURES, AND GIVE IT WHOLLY OFF AT HIGHER TEMPERATURES.

Remark. The character of this section will be shown by heating red lead. See the next article.

MERCURY.

Remarks. This is the quicksilver or *argentum vivum* of old authors. It is generally found in the state of a sulphuret, called cinnibar. It is in the solid state at about 40 degrees below zero, that is, about 72 below freezing—it is in the liquid state to about 600 above freezing, when it is evaporated.

The black oxid or protoxid of mercury is produced by agitating mercury in contact with atmospheric air.

Illustration. The easiest method of producing the black oxyd is, to put about a gill by measure of mercury in a strong quart stone jug, and let some person take it into a carriage, who is about to travel forty or fifty miles over a rough road. A considerable quantity of the black oxid will be formed in the jug.

Application. The black oxyd formed in this way illustrates the principle of oxydation very satisfactorily. Those who transport mercury in carriages over rough roads, should fill the vessels containing it quite full. I once had more than a pound of mercury converted into the black oxyd, on the road from Pittsfield, Mass. to Troy; a distance of about 35 miles. This is the *Ethiops per se* of old authors.

The red oxyd or per-oxyd of mercury, is produced, by heating mercury in contact with atmospheric air.

Illustration. Put a little mercury in an iron ladle, and heat it almost to its boiling point. Its surface will soon become covered with glimmering spangles, which become more reddish and encrease in quantity, till at length the whole mass will become the red oxyd.

Application. This was formerly called *precipitate per se*, as distinguished from the red precipitate. It is now called *hydrargyri oxydum rubrum* in the pharmacopœias.

Mercury combines with nitric acid and forms nitrate of mercury.

Illustration. Put some mercury into a wine glass and pour in nitric acid diluted with about one fourth its measure of water. Let the mercury be in excess and nitrate of mercury will form and crystallize, without any evaporation.

Application. This salt is used in medicine by some physicians. It is also used as a test, and in several chemical experiments.

The nitrate of mercury may be reduced by heat to the nitric oxyd of mercury, called red precipitate.

*Illustration. Put the salt into an earthen plate and apply a moderate heat, until it is reduced to a dry white mass. Then pulverize it very finely in Wedgwood's mortar, and put it into a florence flask, stop it loosely with a glass stopper and set it into the lead pot or in a sand bath. Raise the heat moderately, until the powder becomes bright red; it will then assume the appearance of scales.

Application. This is the red precipitate used in medicine. This is the substance which is boiled with prussian blue to obtain the prussiate of mercury, from which the prussic acid is disengaged.

Sulphur and mercury will unite without heat by being rubbed together, and form the black sulphuret, called Aethiops mineral.

Illustration. Put equal quantities by weight of mercury and pulverized sulphur in Wedgwood's mortar and rub them with the pestle until there is no appearance of liquid mercury.

Application. This sulphuret is used in medicine.

Mercury will combine with sulphuric acid by heat, and form the per-sulphate of mercury.

*Illustration. Put some mercury into a florence flask and pour in about as much strong sulphuric acid; it is better to put in about one eighth more of the acid by weight. Set the flask into the lead pot or over coals and boil the contents moderately, until it becomes a dry white mass. Now take the flask from the fire and cork it up tight, or it will absorb water very soon from the atmosphere and become liquid.

Application. This caustic salt is not much used in this state ; but it is used for making corrosive sublimate and calomel. An article in the materia medica called *turpeth mineral* is made by merely throwing this salt into boiling water, after it is finely powdered. It immediately becomes a yellow powder and must be washed several times in warm water before it is put up for use.

If per-sulphate of mercury and muriate of soda be heated together, a double decomposition will take place, and per-muriate of mercury, (oxy-muriate) *called corrosive sublimate, will be produced.*

*Illustration. Put dry per-sulphate of mercury into Wedgwood's mortar and about a third more by weight of common table salt. Rub them well together, and put the mixed powder into a florence flask, stopping it loosely with a glass stopper. Set the flask into the lead pot and apply heat. A decomposition will take place, and the corrosive sublimate will be sublimed : That is, by raising the heat gradually it will shoot up in crystals along the sides and into the neck of the flask. After the crystals stop shooting up, take out the flask and break a hole through the bottom carefully, still keeping it in an upright position. The hole must be about as large as the whole bottom of the flask, through which all the black residue must be discharged. Now scrape out the crystals, and put them up for use.

Application, This exhibits the principle in a cheap way. But a very different apparatus is adopted, for manufacturing corrosive sublimate in a large way. It is called oxymuriate of mercury ; but as it consists of muriatic acid combined with the per-oxid of mercury, without any oxymuriatic acid, it is properly the per-muriate of mercury. It is a deadly poison.

Per-muriate of mercury may be reduced to the proto-muriate, called calomel, by being rubbed with an additional portion of mercury, and the mixture heated.

*Illustration. Put corrosive sublimate into Wedgwood's mortar, and add about half as much by weight of mercury. (It is rather more safe to add about an eighth more mercury.) Rub them well together, until there is no appearance of mercury ; it having all become a powder. Now put it into a florence flask and sublime it, as when making the corrosive sublimate. After subliming once, it ought to be scraped out, powdered in the mortar and sublimed again, in order to be pure and fit for use.

Application. This is the calomel used in medicine. It is called sub-muriate of mercury. But as it consists of muriatic acid combined with the protoxid of mercury, its true name, according to correct nomenclature, is proto-muriate of mercury. But if we adopt the chlorine doctrine, the sublimate of mercury is *perchloride* of mercury, and the calomel is *proto-chloride* of mercury.

This method of preparing those salts appears wasteful ; but the florence flasks can be had for half a dollar per dozen, and there is no other method within my knowledge of experimenting so cheaply.

Nitrate of mercury, heated with alcohol, may be formed into an explosive, or fulminating powder.

*Illustration. Make the nitrate of mercury by heating the mercury with about ten times as much nitric acid, by weight; which will be in a liquid state. After it is cool, pour it into a florence flask with about one fourth more alcohol. Apply a moderate heat until effervescence commences, and no longer. After effervescing a while, and producing fumes on the surface, a powder will begin to be precipitated. When the process ceases, pour off the liquid, wash the powder several times immediately in pure water, and then dry it on paper. It must be dried without exposing to much heat, or it will explode while drying.

Application. By striking a small quantity of this powder with a hammer on an anvil, it will explode violently. It will explode by compression under the foot on a pavement, if well dried. It is used in various mixtures for small fire-works, &c. Though it is not so dangerous an article as fulminating silver, it ought to be made in very small quantities only, and very little exploded at once. As it explains no principle, which cannot as well be explained by experiments of less danger, it will generally be most advisable to omit it in the course here proposed.

Corrosive sublimate, the per-muriate of mercury, may be detected by an orange-yellow precipitate, made with lime-water.

Illustration. Dissolve some of this corrosive salt in water, and then pour into it some lime water; immediately an orange-yellow precipitate will appear.

Application. Although this is a good test, there is so much difficulty in obtaining the salt from the stomach of a dead body, that circumstantial evidence ought rather to be relied on, than the opinions of physicians founded on such an examination. It is more soluble than arsenic; consequently more difficult to obtain from among the liquid contents of the stomach.

LEAD.

Remark. Lead is generally found mineralized with sulphur, in an ore called galena. It is much used in the arts in the metallic state. It is alloyed with tin, forming pewter. Good pewter consists of one part lead to four of tin; but most of the pewter of the present day is chiefly lead. Solder, called plumber's solder, consists of equal parts of lead and tin melted together.

Lead receives its lowest proportion of oxygen at a low red heat, while exposed to atmospheric air; also from the decomposition of an acid, with which it is combined as the base of a salt.

*Illustration. Melt some lead in a ladle, and scrape off the pellicle which forms on its surface several times, or until a sufficient quantity is obtained. Part of this is oxydated, and part is not.—Now put this into the ladle by itself and expose it to a low red heat, continually stirring it with a rod until it becomes of a yellow colour. This is the protoxid, yellow oxyd, or *massicot*.

Or it may be obtained by forming the nitrate of lead in the same manner as directed for forming the nitrate of mercury, and then by heating the salt to redness in a ladle, covered over pretty closely.—The acid is driven out, leaving the protoxid of lead.

Application. This is the *massicot* used in the arts. It is also an useful powder for setting a fine edge to razors, for polishing burnishers, &c.

The protoxid of lead will become the deutoxid, by exposing it to atmospheric air in a strong heat, not quite bringing the powder to a state of fusion.

*Illustration. Put some massicot into a ladle, and cover it over loosely with an earthen or iron plate, and raise the heat. Raise up one end of the plate and stir it often, until it becomes of a bright red. Care must be taken not to raise the heat so high as to drive off the previously acquired oxygen, and thereby bring it again to the state of pure melted lead. It is, in fact, difficult to perform this operation with small quantities.

Application. This is *red lead* or *minium*, used by painters. On this principle, though with very different apparatus, red lead is manufactured for the shops. But the red lead of the shops is generally very impure. It often contains red ochre, silex, alumine, muriate of lead, sulphate of lead, &c.

Minium becomes litharge by heating a considerable time in as high a heat as it can bear, without parting with its oxygen.

*Illustration. Put some red lead into a ladle, and heat it until it is partly melted, so that it begins to be agglutinated in a kind of scales.

Application. This is the semi-vitreous oxyd of lead, usually called *litharge*. It is not so bright a red, but is a more durable colour.

By raising the heat very high, oxyd of lead gives its oxygen wholly off, and becomes pure lead again.

Illustration. Put some red lead into a ladle and raise the heat as high as the white heat of iron; and pure metallic lead will be found in the ladle.

Application. This last experiment is an illustration of the distinctive character of this section.

Red oxyd of lead will decompose muriate of soda, with heat, and form the patent yellow.

Illustration. Pulverize common table salt very finely and put it into Wedgwood's mortar. Put in with it twice as much finely pulverized red lead. Rub them well together first; then add water, a very little at a time, and continue rubbing until a paste is formed. Muriate of lead will now be formed, and the soda will be disengaged. Pour in a large quantity of water and wash it several times. The soda will wash out and leave a white mass. Dry this mass and then melt it in a crucible; and a beautiful substance will be formed, called *patent yellow.*

Application. The patent yellow is one of the most durable pigments, and may be made very good in this way.

Carbonate of lead, called white lead, is formed by double decomposition on mixing nitrate of lead and pearlash.

Illustration. Make nitrate of lead as before directed and dissolve it in water in a wine glass.— Pour into it a solution of pearlash, and a white insoluble precipitate will fall down. Let the liquid be poured off, and the powder washed several times.

Application. This is the *white lead* of painters in its purest state. It is generally made in the large way by applying the vapour of vinegar to sheet lead. It will of course contain some acetate of lead and other impurities.

White lead, carbonate of lead, dissolved in vinegar, forms sugar of lead.

*Illustration. Put some white lead into a florence flask. Put in about ten times as much good sharp vinegar (distilled vinegar is best.) Shake it up several times and let it stand until the vinegar tastes sweet. Add more vinegar and continue adding by littles, until it will remain sour. Evaporate and crystallize in the usual way.

Application. This is the acetate of lead or sugar of lead, used in medicine. It is called sugar of lead on account of its sweet taste.

Lead is precipitated from the state of a salt in the metallic state by metallic zinc.

Illustration. Dissolve sugar of lead in thirty or forty times its weight of water. Fill a decanter with this solution. Suspend a small clean bright piece of zinc in the liquid by a thread, which is held by being compressed by the side of the stopper. Set the decanter in a conspicuous place in the class-room where it may remain a day or two undisturbed. The acetate of lead will be decomposed. The lead will cover the zinc with leaves shooting out in a curious manner, while the sour taste of the vinegar is partly restored.

Application. Zinc having a stronger affinity for oxygen than lead, it takes so much from it, that it cannot hold the vinegar any longer in combination with it.

Remark. Nickel is too rare a metal to be subjected to experiment in this course.

ANALYSIS

OF MINERALS, MINERAL WATERS AND SOILS.

Remarks. To analyze minerals expertly and accurately requires the practice of several years, and an extensive collection of the most perfect tests.—The presence of common metals may be detected without much difficulty. The substances which are usually held in solution in the mineral waters of our country may also be detected without a laborious process. But to determine the proportions of the parts of a compound mineral, or the quantity of any substance contained in mineral waters, requires more practical instruction than can be communicated in the course here proposed. The most excellent part of M'Neven's Brande, in my opinion, is the analysis of Minerals and Mineral Waters. To that work all those are referred, who wish to extend their knowledge of these subjects.

ANALYSIS OF MINERALS.

Remark. I shall confine my directions exclusively to the metals; for the analysis of earthy compounds is too complicated for the course proposed.

As the hydrosulphuret of ammonia will precipitate the oxyds of all metals, which form the bases of salts, the colours of the precipitates may assist in detecting metals.

Illustration. Put solutions of several metallic salts (as copperas, blue vitriol, white vitriol, sugar of lead. lunar caustic, &c.) into separate wine glasses, and pour in a little hydrosulphuret of ammonia into each, and observe the different coloured precipitates.

Application. Dissolve a supposed metal in an acid—as sulphuric, muriatic, nitric or nitro-muriatic. Prepare a solution of a known metallic salt, as before directed, having a base of that metal which is suspected to be under examination. Pour some hydro-sulphuret of ammonia into both, and compare the colours, densities and other characters of the precipitate. Although this will not always afford conclusive evidence, it will assist in directing the judgment.

An infusion of galls will precipitate the oxyds of many of the metals, which form the bases of salts; and the colours of the precipitates may assist in detecting such metals.

Illustration. Rasp off a quantity of a nut-gall and soak it an hour or two in pure water. Strain off the liquid and put it into a vial for use. Dissolve several metallic salts as directed in the last experiment, and precipitate the oxyds of the metals from their acids with the infusion of the nut-galls, and observe the colours of the precipitates.

Application. Metals may be tested by being reduced to salts and by collateral or comparison experiments as directed when using the hydrosulphuret of ammonia. It must be understood, that the same metal sometimes gives different coloured precipitates, when in different degrees of oxydation. The following are some of the colours, as taken from Brande. With the proto-muriate of *manganese*, dirty yellow—proto-sulphate of *iron*, purple—per-muriate of *iron*, black—muriate of *tin*, dirty yellow—proto-muriate of *tin*, (acid) straw colour—per-muriate of *tin* (acid) fawn colour—proto-muriate of *copper*, yellow brown—per-nitrate of *copper*, grass green—nitrate of *lead*, dingy yellow—tartrate of *antimony* and potash, straw colour—tartrate of *bismuth* and potash, yellow—sulphate of *uronium*, bluish black—muriate of *titanium*, (acid) brown—sulphate of *titanium*, blood red—white oxyd of *arsenic*, scarcely changed—any salt of *molybdena*, brown—sulphate of *nickel*, green—proto-nitrate and per-nitrate of *mercury* (acid) yellow—nitrate of *silver*, curdy becoming brown—muriate of *platian*, brownish green.

These two tests, together with the characters of the metals given under their respective heads, may be sufficient for common use. In very difficult cases, recourse must be had to extensive works on chemistry.

It will be perceived, that these tests will apply to the analysis of mineral waters, when any of these metallic salts are suspected in them.

ANALYSIS OF MINERAL WATERS.

The following directions will be sufficient for detecting those substances which most commonly occur, and in the largest proportions in the United States. Prepare the following waters artificially, and test them before the class:

In searching for any of these substances, it will be advisable to use the test for that first which we have the most reason to expect.

MURIATE OF LIME. *Nitrate of silver* in solution dropped into the water gives a dense white cloud if it contains muriatic acid. *Oxalic acid* gives a light white cloud, if it contains lime. Oxalate of ammonia is better.

SULPHURETTED HYDROGEN. *Acetate of lead* in solution is precipitated dark brown.

CARBONATE OF IRON. *Tincture of galls* gives a dark purple, and at length a brown colour, if it contains iron. *Boiling* will drive off the carbonic acid, so that after it has stood a while the iron will be so completely precipitated, that the supernatant liquid will not give the test with tincture of galls.

SULPHATE OF IRON. *Tincture of galls* gives the dark colour both before and after boiling.

FREE CARBONIC ACID. *Lime water* gives a white cloud before boiling, but produces no effect after boiling.

SULPHATE OF MAGNESIA. *Muriate of Barytes* gives a cloud, if water contains sulphuric acid. If *red cabbage* does not give the acid test, the sulphuric acid is combined with a base. If the *tincture of galls* and *oxalic acid* give no test of iron or lime, we may presume the base to be magnesia. To be more sure, evaporate the water by a very gradual heat, and taste the dried residiuum. If it has a bitter taste, it will be a confirmation of the tests.

MURIATE OF SODA. Test the muriatic acid by *nitrate of silver*. If *oxalic acid* does not give the test of lime, evaporate it slowly to dryness and taste it. No one can mistake the taste of common salt.

Incompatible salts are often mentioned in books. But these incompatible salts often exist together while the water is cold; but as soon as the water is heated, decompositions take place.

The preceding are not given according to the nice directions of the books; but they will serve as a convenient guide,

If *lead* be suspected in water which has passed through leaden aqueducts, pass *sulphuretted hydrogen gas* into a portion of it, and if it contains lead, it will instantly exhibit a dark brown tinge.

If *copper* is suspected in water, or in any article of diet which has stood in a copper vessel, pour into it liquid ammonia, and it will become blue.

N. B. Always institute collateral experiments upon known substances, which are similar to those for which you are searching. In doing this, make use of very minute portions; because large quantities may alter the appearance.

When it is required merely to know whether the water is of that kind called hard-water, without regard to the kind of substances held in solution, dissolve a small piece of fine hard soap in alcohol, and pour a few drops of this solution into the water. If it is hard water, it will become milky—if not, it will remain limpid.

ANALYSIS OF SOILS.

The following formula was adopted by Dr. T. R. Beck and myself, in analyzing the soils of Albany county, September, 1820; also, of Rensselaer county, in 1821.

1st. A quantity of the soil, including gravelly pebbles of the smallest kind, is pulverized in a Wedgwood's mortar.

2d. Parcels of two hundred grains each are separately weighed: three of them, if it is intended to ascertain the proportion of iron; two, if not.

3d. One of the parcels is put into a crucible and heated gradually, constantly stirring it with a dry pine stick, until the stick becomes a little brownish from the heat, on pressing it against the bottom of the crucible.

4th. The above is then carefully poured into the scales and again weighed. What is deficient of the 200 grains, is set down as *water*.

5th. The parcel is then returned into the crucible, and heated to a high red heat. It is frequently stirred with a glass rod, and the heat is continued until the mass presents no shining sparks. After allowing it to cool a little, it is returned into the scales again, and what it wants of its last weight after being dried, is set down for the *animal and vegetable matter*. Part of this is undoubtedly water, but probably is not more than should always be considered as attached to this part. It may here be added, that there will be no blackness in the appearance of the soil, if it has been sufficiently heated.

6th. Let it now be poured into an assay glass, and add half a pint of pure water to it. After repeated stirring for ten minutes, let it stand about three minutes, to allow the siliceous matter to settle. Then pour off all which stands over the silicious part into another glass. Dry this sediment in a high read heat, weigh it and set it down for the *silex*.*

7th. Let the part which was transferred to another glass, stand until it settles, leaving the liquid clear. Pour off the liquid into another glass, dry this sediment with a high red heat, weigh it, and set it down for the *aluminous part*.†

8th. The remaining liquid is then evaporated in

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* This is not pure silex. But grains and pebbles in soil have the same effect upon vegetation, if sapphire (nearly pure alumine) as if a quartz (almost pure silex.) Perhaps we ought to call this part of soil by some other name. We mean that part of soil which cannot be dissolved nor even mechanically suspended in water, and is not carbonate of lime.

† This is not a pure alumine. But its strong attraction for water causes it to be longer suspended in water; and on that property depends its peculiar effects upon vegetation.

a glass evaporating dish. The solid residuum is scraped off, and weighed for *soluble salts.*

9th. The other parcel of two hundred grains is put into a florence flask, in which half a gill of equal portion of muriatic acid and water has previously been poured, and which has also been balanced by weights in the scales. After allowing it to stand about three hours, it is ascertained how much less than 200 grains is to be added to the weight, in order to balance the flask. This is considered as the weight of the carbonic acid that has been expelled. Then by the table of component parts, as 44 is to 56, so is this weight to the weight of the base. The *carbonate of lime* in the soil is thus ascertained. The lime, however, must be subtracted from the silex, and the weight of the carbonic acid must be deducted from the animal and vegetable matter; since the heat that burnt out the animal and vegetable matter, also expelled the carbonic acid, and left the lime with the silex.

We are aware that part of the quick-lime may remain with the soluble salts, and part of the carbonic acid may still remain with its base and the silex. The error, however, will be of no consequence in agriculture.

Particular attention is paid to the time required for the alumine to settle. It is observed, that in soils which are adhesive, and retain water a length of time, the time necessary for the alumine to settle, is in the same proportion. It is also found to be a much better criterion for determining the measure of this quality, than the actual proportion of alumine.

Average specimens of soil, from near Albany and Troy, N. Y.

Upland loam. Silex 67 per cent—Alumine 22—Carbonate of lime 1—Soluble salts 1—Decomposed animal and vegetable matter 5—Water 4=100.

Best lowland loam.. Silex 55—Alumine 25—Carbonate of lime 2—Soluble salts 1—Decomposed animal and vegetable matter 12—Water 4=100.

Best river alluvion where water stands three or four feet below the surface. Silex 75—Alumine 7—Carbonate of lime 3—Soluble salts 1—Decomposed animal and vegetable matter 11—Water 3=100.

Note. If the oxyd of iron is sought, most soils will yield from 1 to 3 per cent.

Iron may be brought to the state of the protosulphate of iron, by boiling a portion of the soil in sulphuric acid. After diluting it largely and letting it settle, pour off the liquid and precipitate the iron with the benzoate of ammonia. This test gives a yellow precipitate; which may be dried, weighed and calculated.

ORGANIC SUBSTANCES.

Remarks. Under organic substances are included the subjects of the vegetable and animal kingdoms. The ultimate elements, constituting all vegetable and animal substances, have been described and their chief properties illustrated by experiments, in the preceding part of this work. But when those simple substances are arranged according to the laws of organization, and endowed with the living principle, phenomena are induced which elude the researches of the chemist.

The constituents of vegetable and animal matter, are properly divided into *proximate* and *ultimate elements*. The proximate elements are those compounds into which animal and vegetable matter may be resolved, and still retain properties most nearly resembling these organic substances, before they were subjected to the process of decomposition. Such as resin, starch, gum—glue, albumen, oil, &c. The ultimate elements are the simple substances into which they may be resolved, by a thorough analysis. Such as oxygen, carbon, &c.

Much progress has been made in this department of chemistry within a few years. But the complex nature of organic matter presents many difficulties, and the analyses are very slow and tedious. By following the directions given by such extensive and learned works as M'Neven's Brande, Gorham's Chemistry, Silliman's Henry, &c. we may succeed in repeating the experiments, necessary for demonstrating the truth of those principles, adopted by the great philosophers of the age. But such a course of experiments would require the labour of many months, or perhaps of years.

Having become practically acquainted with the most important properties of all the elementary constituents of animal and vegetable matter; we are now prepared to understand the descriptions given us by those, who have patiently and laboriously investigated them. We must therefore content ourselves with the history of their labors, and rely upon the truth of their experiments; as we do upon the astronomical calculations of Newton, Le Lande, Herschel and others.

VEGETABLE SUBSTANCES.

ULTIMATE ELEMENTS.

Vegetable matter is essentially composed of carbon, oxygen and hydrogen.

The cruciform family of plants, such as cabbage, mustard, radishes, &c. contain a little nitrogen. In some few plants sulphur has been detected. Potash, lime, soda, magnesia, and silex, have been found in plants.

When vegetable matter is heated in a retort to that degree which is called destructive distillation, the constituent elements assume new arrangements; and carbonic acid, carbonic oxyd, carburetted hydrogen, empyreumatic oil, water, &c. come over, leaving charcoal, and generally some earths and salts in the retort.

After these products are separated, each is analyzed. From the result of these analyses, the proportions of carbon, oxygen and hydrogen are ascertained. Or if we rely upon the analyses of these products, which have been made by chemists, we have only to ascertain the proportions of these products to be enabled to calculate the quantity of the ultimate elements contained in any vegetable substance under examination.

PROXIMATE ELEMENTS.

The best ascertained proximate principles, or elements, of vegetables, exclusive of the acids, are—gum, sugar, starch, gluten, extractive matter including lignin, tannin, colouring matter, wax, fixed oil, volatile oil, camphor, resin, narcotic principle, bitumen and caoutchouc.

These elements are separated by cold water, hot water, alcohol, ether, or acids. The instructor may exhibit each of these substances to the class and explain some of their properties. But they cannot be extracted before the class in a course of instruction.

Remarks. Experiments illustrating the properties of these substances will not be described; because the suggestion of common sense will furnish all the directions required. It will not be expedient to detain a class with many experiments upon them, if any.

Gum. Soluble in water and in alkaline solutions, but not in alcohol. Consists of 53.4 oxygen, 6.6 hydrogen and 40 carbon.

Sugar. Less soluble in alcohol than in water. Sugar is purified by boiling with blood of cattle, which brings to the surface all impurities. By heating sugar with nitric acid, oxalic acid is formed. Alkalies in solution mixed with sugar in solution, destroy its sweetness; which is restored by a due portion of acid. Consists of 51.3 oxygen, 6.8 hydrogen, 41.9 carbon.

Starch. Starch may be washed from dough. Soluble in hot water, insoluble in alcohol and ether. By heating starch with a little diluted sulphuric acid it may be converted into sugar. It consists of 48.5 oxygen, 7 nitrogen, and 44.5 carbon.

Gluten. It is the adhesive part of flour. Hardly soluble in water or ether. What is called the raising of dough cannot be effected where there is a deficiency of gluten; consequently Indian meal, when made into bread, requires the aid of the gluten of wheat or of rye flour. The process of raising dough is as follows: By the aid of yeast fermentation is excited, which causes carbonie acid gas to be formed. If the dough be made of Indian meal, the gas will escape; because there is no gluten to detain it. But if it be made of the flour of wheat, the carbonic acid gas, which is formed in every part of the mass, is arrested by the adhesive property of the gluten. As the gas continues to encrease and to expand, the whole mass is blown up into an immense number of vesicles. This aids the process of baking; because instead of requiring heat sufficient to penetrate the solid mass, no more is required than what is sufficient for the thin walls of the vesicles, of which it now consists. Pearlash will furnish carbonic acid gas in abundance, by being decomposed with the vegetable acids produced in the dough.

Extractive matter including lignin. These are very vague and undefined substances, comprising the woody part as well as the most important principles of the plant which can be extracted.

Tannin. An astringent principle in vegetables. It is abundant in nut-galls, oak-bark, &c. It has a strong affinity for animal gelatin with which it unites in making leather of skins.

Colouring matter. As this is connected with other vegetable principles, it depends on them for many of its properties. It is attracted with different degrees of force by the different stuffs. Strongest by wool, next by silk, next by cotton, and least by flax and hemp. Several of the salts attract colouring matter with considerable force, which attract the stuffs also. These serve as the bond of union between the colouring matter and the stuffs. Such as copperas, alum, muriate of tin, &c. These substances are called mordants; and they frequently change the colour, at the same time that they assist in fixing it.

Wax. Vegetable wax is found on the surface of the fruit of the bay-berry, *(Myrica cerifera.)* Bees-wax is also a very perfect vegetable wax, when purified and in the state of white wax. It is soluble in heated fixed oils, when it forms the cerates of physicians. Some of the volatile oils dissolve it also. It is soluble in potash and soda, forming a soap-like compound. It is not much affected by acids; therefore it is useful in etching, luting, &c.

Fixed Oils. Vegetable fixed oil is pressed from the flax-seed in large quantities; and is much used by painters. Castor oil, which is pressed from the castor bean, (Ricinus communis,) is used in medicine. Fixed vegetable oil may be pressed from the fruit of the walnut, butternut, &c. Olive oil is also an important fixed oil. A fixed oil may be separated into the concrete part, *(stearine)* and the fluid part (*elaine.*) And they are more or less inclined to retain the liquid state, according to the proportion of *elaine* contained in them.

Some oils readily become hard and resinous on exposure. These are called *drying oils.* They are used in the manufacture of printer's ink. It is pretty highly heated, set on fire and burned about half an hour, then extinguished and boiled down until it is of a suitable consistency. Afterwards it is mixed with some spirits of turpentine and lamp-black. Nut-oil is preferred for printer's ink; but linseed oil is often used.

Fixed vegetable oils combine with the alkalies and form soap. The best hard soap is made of olive oil and soda.

Volatile Oils. These oils are very numerous. They are distinguished from fixed oils by being converted into a state of vapour by heat; whereas fixed oils cannot be vaporized or volatilized without combustion, and, of course, decomposition. Some of the most common volatile oils are, spirits of turpentine, oil of lemons, juniper, rosemary, tansy, wintergreen, mint, (called peppermint essence,) pennyroyal, fennel, cloves, cinnamon, aniseed, dill, &c. They are highly soluble in alcohol, but hardly soluble in water. They are mostly obtained by steeping vegetables in water, and then distilling over in common stills. They are generally called essences, because they contain the essence of the sensible qualities of the vegetable.

The volatile oils become thick and somewhat resinous by the absorption of oxygen on long exposure to air. It is probable that volatile oils become indurated and give strength and durability to the woody fibre by drying. For when timber is water seasoned, as it is called, (that is, soaked in water a while and then dried to prevent its shrinking,) it is more easily broken and decays sooner. Wood is found to be less valuable as fuel, which is cut down while green and exposed to rains. In both cases the volatile oil is extracted more or less by water. It is therefore better for fuel or timber when it is cut down in a green thrifty state and dried or seasoned under a shelter. If a volatile oil is adulterated by a fixed oil, it may be detected by rubbing a little of it on paper, and holding it near the fire. The volatile oil will evaporate and leave a greasy spot on the paper, which is made by the fixed oil. The essence-pedlars generally purchase a small quantity of the volatile oils, and then adulterate it largely with alcohol. This is a very common fraud, and ought to be detected and exposed, which may be done by pouring a few drops into a wine glass of water. The pure essence will float on the water, and scarcely mix with it at all. But if it is adulterated with alcohol, it will mix with the water and a change in colour, &c. will instantly appear.

Camphor. This substance is obtained from the camphor tree of Japan, (*Laurus camphora.*) This is a species of the same genus with the sassafras and spice-bush of our country. And the camphor has many properties in common with the volatile oil of sassafras and of other vegetables. It is soluble in alcohol and hardly soluble in water; it dissolves in both the fixed and volatile oils.

Camphor may be made artificially. At least a substance is deposited very similar to camphor, by passing a current of muriatic acid gas through spirits of turpentine.

Resins. The juice which exudes from the white pine and several other species of the genus *pinus*, consists of the resin and the volatile oil, called spirits of turpentine. By distilling over the latter, the former remains pretty pure.

Pure resin is insoluble in water, soluble in alcohol and the alkalies, and almost devoid of taste or smell. Those which do give off any odour, are combined with volatile oil; and are generally denominated *balsams*. Besides those resins which come under the general denomination of pitch, are the guaiacum, copal, mastich and others; the two last of which are hardly soluble in alcohol. There are several hard resins, called *lac*, which are deposited by an insect of the East Indies on twigs of trees, &c. The most common of these is called shell-lac.

There are compounds of gum and resin, called *gum-resins*. Gamboges and assafoetida are of this kind. As gum is soluble in water and resin in alcohol, it requires both for their solution. *Amber* is placed under resins; but it is hardly soluble in alcohol or in the alkalies.

Narcotic principle. There is a substance in opium in which the narcotic principle resides. The same substance may undoubtedly be found in all other poisonous vegetables of the narcotic kind. It is sometimes called *morphia*, on account of its inducing sleep.

Bitumen. This substance partakes something of the nature of oils and of resin. When pure, it is a limpid liquid, and is then called *naphtha*. It consists of about 87 per cent carbon and 13 per cent hydrogen. As it contains no oxygen, the inflammable bases of potash, &c. are kept in it.—When in the state of a brownish or iridescent liquid, as it is seen floating on stagnant waters, it is called *petrolium*. When in the solid state, as it is found in Trinidad, and on the shores of Lake Asphaltides, it is called *asphalt*.

VEGETABLE ACIDS.

The ultimate elements of vegetables may be so combined as to form compound acidifyable bases; these bases may be acidified and form vegetable acids—as tartaric acid, oxalic acid, citric acid, malic acid, gallic acid, benzoic acid, &c.

Tartaric acid. This acid is produced by several of the fruits; but the grape furnishes it in the largest quantities. It is collected chiefly from wine casks after the wines are drawn off.

It is sold at the shops in the state of tartrate of potash, super-tartrate of potash, (cream of tartar) and tartaric acid. Tartrate of antimony, or emetic tartar, consists of this acid combined with the protoxid of antimony.

Oxalic acid. This acid may be obtained by soaking green wood-sorrel in pure water a short time, and then pressing out its juice into the water. I have obtained the best acid from the yellow flowered wood-sorrel *(oxalis stricta)* which grows in open fields. It is the test for lime in mineral waters,* &c. This acid is made artificially with sugar and nitric acid, as mentioned under sugar. The proportions to be heated together are, white sugar dissolved in twice as much water, and then boiled in a florence flask with four times as much nitric acid as sugar. Vid. M'Neven's Brande, p. 497. Oxalic acid taken in large quantities is an active poison. Authors who assert this, refer to the artificial acid. I can hardly believe it to be a poison in its natural state. For being a pleasant acid, the plant

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* I put some of the expressed juice of the oxalis stricta into a vial at Hudson in August 1819. In June 1820, this was found to be a good test for lime; though it had been frozen several months in the time.

is eaten in great quantities by children as well as by adults; and I never heard of any evil consequences.

Citric acid. The acid of lemons and limes. It is a cooling pleasant acid well known. It consists of 54.8 oxygen, 4 hydrogen, and 41.2 carbon. It is applied to iron rust spots on cotton and linen, when it forms citrate of iron which is colourless.

Malic acid. The acid of green sour apples. The taste is harsh and unpleasant. It is also applied to iron rust spots, as the citric acid. It consists of 54.9 oxygen, 16.8 hydrogen, 28.3 carbon.

Gallic acid. This is produced in abundance in the common nut-galls from the Levant. It is found in the nut-galls of some species of the American oak also. It is contained in oak-bark, &c. From any of these substances it may be obtained by soaking them in water. Though not pure, it will do very well for common use. Gallic acid and the oxyd of iron form the basis of writing ink. Its use as a test has been shewn. It consists of 38.4 oxygen, 5 hydrogen, 56.6 carbon.

Benzoic acid. This acid is sold in the shops in fine white needle-form crystals, called *flowers of benzoin.* It is obtained by sublimation from what is called gum benzoin; being a resinous exudation from the *Styrax benzoin* of Sumatra. It is used in medicine, and forms a salt with ammonia, called *benzoate of ammonia,* which is an excellent test for the presence of the oxyd of iron. It is prepared by dissolving the acid in water, and then by dropping in the carbonate of ammonia until effervescence ceases.

Remark. There are many other vegetable acids; but they are of minor importance. Such as the boletic acid from touch-wood, &c.

PRODUCTS OF FERMENTATION.

Some vegetable solutions will undergo spontaneous changes, whereby alcohol or vinegar is produced; during this process carbonic acid gas is evolved.

Illustration. Put some sugar into a florence flask, and dissolve it with about five times as much warm water, and add a little yeast. Set it where it will continue to be warm, but not hot. Let one end of a bent tin or glass tube be fitted into the flask by perforating a sound cork, and let the other end pass under the moveable shelf of the cistern. After standing a while, a gas will begin to come over.—As soon as the atmospheric air has passed out, begin to collect the gas. On testing it with lime-water, it will be found to be carbonic acid gas.

Application. From this experiment it appears, that sugar alone is sufficient to produce fermentation with water, when started with yeast. It is found that sugar is essential by many trials. This is the same gas which issues from cider, beer, &c. when fermenting—it is also produced in dough when rising, as before described.

The intoxicating substance, called alcohol, is produced during fermentation. Alcohol being converted into vapour with less heat than water, it may be distilled over by a due degree of heat.—Thus rum, brandy, gin, cider-brandy, &c. are obtained.

Cider is sometimes boiled down for family use; as for making apple preserves, &c. This should always be done before fermentation commences; because alcohol will then be formed, which will be driven off and wasted by evaporation, while boiling down the cider.

The ardent spirits of commerce consist of alcohol combined with water, and some other adulterating substances, giving each kind its peculiar flavor; from either of which pure alcohol may be obtained by re-distillation, and the absorbing power of potash.

Illustration. Fill a pint retort half full of common proof whiskey. Fit the beak to a receiver and surround the neck with beeswax where it enters the receiver; so that if water is applied to the neck of the retort it cannot run into the receiver. Let the receiver be immersed in cold water, or surrounded with snow. Set the retort into the lead pot over coals in the usual way, and raise the heat by the hand-bellows. Set the lead pot so near the cistern, that cold water may be poured on the neck of the retort and be renewed in the vessel where the receiver is immersed, without wetting the room. Alcohol will rise up in vapor and be condensed in the neck of the retort, and run down into the receiver. After the measure of the alcohol in the receiver about equals the measure of what remains in the retort, stop the process.

Put into a tumbler a quantity of pearlash, about equal in weight to one fourth of the alcohol distilled over, which had been made as dry as possible on a plate exposed to a little heat, let the pearlash be warm as can be borne by the hand when put into the tumbler, and pour the alcohol upon it. Now stir it up and keep the alcohol in the tumbler with it, about half an hour. Now let it settle and pour off the alcohol for use.

Application. By this method very pure alcohol may be obtained. On the same principle, with large retorts and receivers, alcohol may be obtained for the use of the physician and the artist. If carefully distilled and well prepared, it will be so inflammable that if it be poured upon an earthen plate with good gun-powder on the bottom, it will burn down and inflame the powder.

Alcohol has such a strong affinity for water, that on mixing them they unite so closely as to diminish their measure, or volume.

Illustration. Fill the bulb of a bolt-head, or long-necked matrass, with water. Incline it a little, and pour in alcohol to fill the neck almost full. Let it glide down slowly along the inside of the neck, so that it may chiefly float on the surface of the water. Having previously tied a piece of a thread around the neck, slide it to the precise level of the surface of the alcohol. Now put the thumb over the mouth of the bolt-head, and shake it so as to mix the two liquids. It will now be seen that the surface of the combined liquids is considerably lower than the thread.

Application. This diminution of the measure of the liquids encreases their specific gravity. Consequently the reduction of alcohol by water is not indicated directly by the increase of the specific gravity. When perfectly pure the specific gravity of alcohol is 0.79, but it can hardly be obtained below 0.82. Vid. the table in M'Neven's Brande, p. 524. Pure alcohol consists of 34.32 oxygen, 13.70 hydrogen, and 51.98 carbon.

Alcohol, boiled with sulphuric acid, produces a light volatile compound, called ether.

Illustration. Having fitted the beak of a retort to a tubulated receiver, as directed in obtaining alcohol, immerse the receiver in cold water, or surround it with ice. Raise the heat in the lead pot considerably; but do not put in the retort yet. Put some alcohol into a tumbler, and add the same weight, (or a little more than half the bulk) of sulphuric acid. The acid must be poured in gradually, and well stirred, as it drops in, with a glass rod. If it is poured in fast it will become too hot; but it must not be so hot that the heat of the tumbler cannot be borne by the hand. As soon as it is mixed, set the retort into the lead pot, and immediately pour into it the mixed liquids through the tubulature, and put in the stopper. Raise the heat to a little below the boiling point of water immediately, and keep it at that temperature. This may be determined by frequently dipping a small stick into hot water, and touching it to the hottest part of the retort. It must not be quite hissing hot. If the stick is dipped in cold water it may break the retort.

Continue the process until the whole liquid in the retort begins to rise up. Then either stop the process, or pour in half as much alcohol as at first, and more may be brought over. If the vapour presses too hard during the process, open the tubulature of the receiver an instant, occasionally.

Application. By adopting this method of preparing ether, with large retorts and receivers, physicians and artists may prepare the best of sulphuric ether, and thereby avoid both expense and imposition.

Ether is extremely volatile; so that if a part of the atmospheric pressure is taken off, it will boil mith the warmth of the hand.

Illustration. Put a little ether into a long-necked vial (a Cologne vial is best.) Heat the vial so that it can hardly be borne by the hand, while its mouth is open. Then put in the cork perfectly tight. Now if a warm hand be clasped around the neck of the vial, and it be held with the bottom up, the ether will boil.

Application. This experiment is an additional confirmation of the principle given under Caloric at p. 44. It exhibits the volatile nature of ether also, upon which much of its usefulness depends.

Fermented liquids which produce alcohol will undergo a second fermentation, if exposed to warm atmospheric air; in which state the alcohol will be destroyed and vinegar will be produced.

Illustration. Expose a little cider, strong beer, or wine to a summer's sun, or to the air of a warm room in an open bowl or an earthen plate, and in a few days, or sometimes in a few hours, it will become acetous, and loose all its alcoholic principle.

Application. Upon this principle common vinegar is made. Oxygen is absorbed from the atmosphere, which is supposed to unite with and carry off another proportion of carbon in the state of carbonic acid gas. Pure acetic acid consists of 46.82 oxygen, 6.35 hydrogen, 48.83 carbon.

If good sound wood be heated in a confined situation, as in a gun-barrel, &c. the *pyroligneous* acid comes over, which makes good vinegar when seperated from several impurities which come over with it. Vast quantities of this acid are produced in the manufacture of charcoal for making gunpowder.

Acetic acid, the pure basis of vinegar, is best obtained by combining common vinegar with the oxyd of a metal forming a salt, as acetate of copper (verdegris) acetate of lead (sugar of lead) and then distilling it over by heating the salt to redness.

When wine becomes partly acetous, called pricked wine, the disagreeable taste is often corrected by sugar of lead. It is then poisonous, and the fraud ought to be detected. This may be done by dropping it into a little water, charged with sulphuretted hydrogen gas. It will immediately become dark brown.

SPONTANEOUS COMBUSTION.

Some vegetable substances will become ignited and burn spontaneously, if brought into contact with certain acids and salts.

Illustration. Pulverize about a table-spoonful of white sugar and dry it on a plate, being careful not to melt it. Mix with it about one sixth as much oxymuriate of potash; and put a little on the top of the mass, unmixed. Now dip a lump of white sugar into strong sulphuric acid, and touch it to the oxymuriate of potash on the top of the sugar, and the whole will immediately become inflamed and burn vehemently.

Put half a table spoonful of spirits of turpentine into a wine glass. Put half as much sulphuric acid into another wine glass, and the same quantity of nitric acid into a third wine glass. Pour the two acids into the spirits of turpentine at the same instant, and it will burn rapidly and fly out of the glass in a blaze to a considerable height. A board 3 or 4 feet long and 14 inches wide must be set up between the operator and the glasses on the table to prevent his being injured; and he must reach his arms around each edge of it, and pour in the acids.

Perform the same experiment in the same way, by substituting alcohol for spirits of turpentine, and adding a few grains of oxymuriate of potash.

Application. We often hear of the spontaneous combustion of persons, who have been long addicted to the intemperate use of alcohol in the state of whiskey, brandy, gin and rum. These awful catastrophies cannot be explained in the present state of human knowledge. These experiments may go a little way towards their illustration; though it is acknowledged they are not satisfactory.

ANIMAL SUBSTANCES.

While animals are in the living state, that undescribed something, called the living principle, renders their operations more intricate and complicated than those of vegetables. In both animals and vegetables, there appears to be two active principles at war with each other—these are denominated the *living principle*, and the principle of *chemical affinity*. The latter is deposed to derange the organic structure, and to form new chemical compounds. But the former is the more powerful, and resists the incessant attacks of the latter. Chemical affinity is exerting its energies every moment of our lives to convert our bodies into the most odious gases, and inorganic liquids and solids. But the living principle maintains its empire for a few years. At last yielding to the unabating efforts of chemical affinity, the most beautiful face loses its youthful glow, and the speaking eye loses its brilliancy. They are given over to form the constituent elements of sulphuretted hydrogen, carburetted hydrogen, ammonia, carbonic acid, and other inorganic substances. What now constitutes the symmetry and all the fascinations of beauty, may be converted into the various gases; which, after floating a while at the pleasure of the winds, are absorbed by the earth, and re-appear in the form of a rose, an ear of corn, or the deadly nightshade.

ULTIMATE ELEMENTS.

The essential ultimate elements of animal substances are, carbon, oxygen, hydrogen and nitrogen. Generally sulphur and phosphorus are found in animal matter.

The addition of *nitrogen* causes the most important distinctions between animal and vegetable substance. It being one of the constituents of ammonia, it gives rise to that gas, during the decomposition of animals, by the process called putrefaction. Several other substances are frequently found in animal matter; as, oxyd of iron, lime, soda, potash, &c.

PROXIMATE ELEMENTS.

The most important proximate elements of animal substances are, gelatine, albumen, fibrin and oil.

Gelatine. This substance is commonly seen in the form of *glue* and *isinglass.* Gelatine constitutes a large proportion of the skins of animals, &c. It has a strong affinity for tannin. This will appear by dropping an infusion of tannin (from common nut-galls will do) into a solution of isinglass. A pretty solid precipitate will be formed of the union of tannin and gelatine. On this principle leather is formed; the gelatine of skins combining with the infusion of tannin obtained by soaking bark in water.

Albumen. This substance is the most distinctly exhibited in the *white* of *eggs*. It always contains so much soda as to give the alkaline test with red cabbage. This may be shown by dissolving it in pure water, and dropping in the infusion of red cabbage, which will give the green test of alkalies.

Fibrin. The constituent of the fibrous part of muscles, &c. Fibrin and albumen are the principle constituents of blood.

Oil. This appears in the form of lard, tallow, spermaceti, &c. It is divided into the *stearine* and *elaine* parts like fixed vegetable oil. Oil and albumen are the principal constituents of milk.

Remarks. Several more proximate elements are described by chemists, but they are of little importance to those for whom this work is intended.

BONES AND SHELLS.

Internal bones of animals consist mostly of phosphate of lime. They contain a little carbonate of lime and some animal matter.

External shells of animals are chiefly carbonate of lime. They generally contain a little phosphate of lime, and some animal matter. Those animals which are covered with an external crust, as the lobster, &c. have their covering chiefly made up of nearer equal proportions of carbonate of lime and phosphate of lime, which contains a larger proportion of animal matter.

RESPIRATION.

Oxygen changes the dark colour of blood of the veins, to the scarlet colour of arterial blood.

Illustration, Drop a small mass of dark clotted blood into a vial of carbonic acid gas, and another mass into a vial of oxygen. Place the fingers over the mouth of each, and shake them pretty hard. The blood in the oxygen will become scarlet coloured, while that in the carbonic acid will remain dark coloured. If atmospheric air is now substituted for oxygen, and another portion put in, it will become scarlet coloured, but not so bright.

Application. It appears from this experiment, that oxygen may affect the blood in respiration, so as to produce the necessary change required (at least in the colour) for rendering it a fit material for supplying the waste of the system.

Atmospheric air suffers a diminution of bulk by respiration; and the oxygen is consumed, or diminished in quantity.

Illustration. Put a mouse into a glass cylinder, and invert it over mercury, pressing it down into the mercury for a few minutes at first, so that the pressure of the mercury may prevent the escape of air by the warmth of the mouse. Let the mouse remain until it expires; which will be in about half an hour in a half pint cylinder. The mercury will now be found to have ascended a little in the cylinder. If great exactness is required, let the temperature be regulated by the thermometer; so that the operator may be certain, that the air is not more expanded when the mouse is put in than afterwards.

Now take out the mouse through the mercury, fill a slender tube or test glass with mercury and pour up the contents of the cylinder into it. Turn the open end upwards and hold the finger on it two or three minutes. The gases within it will separate. Carbonic acid will settle at the bottom, and nitrogen will rise towards the top. This may be proved by immersing in the top only, a small burning taper. It will be extinguished two or three times, and afterwards will continue to burn near the top. Let it now stand open several minutes, and then immerse the taper to the bottom and it will be extinguished. The nitrogen being lighter than atmospheric air ascends, and atmospheric air takes its place ; but carbonic acid being heavier remains at the bottom.

Application. Several important principles are illustrated by this experimentt. A crowded assembly in a close room consume the oxygen and give off carbonic acid gas. The excess of nitrogen ascends to the upper ceiling, while the carbonic acid settles down near the floor. Consequently the purest air, or that which contains most oxygen, is between the two.

The diminution of the bulk of air in the cylinder is a strong argument against a late theory of Allen and Pepys respecting respiration. The old theory, which this experiment seems to support in some measure, supposes the change produced in the blood to be caused by an additional portion of oxygen, which is received from the inhaled air, through the thin membranes of the lungs. The theory of Allen and Pepys supposes the blood to be decarbonated, by the union of a portion of carbon given off in the lungs with oxygen of the inhaled air. But this theory requires that the bulk of the air in the glass cylinder should neither be increased nor diminished. For the addition of carbon, in forming carbonic acid, although it increases the specific gravity, does not increase nor diminish the bulk of the gas. See illustration at pages 109 and 110.

Animal effluvia, arising from the beds of the sick or from other sources, may be neutralized by the strong acids in the state of gas.

Illustration. It seems to be proved by observation that such effluvia are combined with aqueous vapor. The ready union of aqueous vapor and the strong acids in the state of gas will appear by first pouring a tea-spoonful of muriatic acid upon a red hot iron shovel, and then pouring a wine glass of water upon it. The acid will rise up in the state of a suffocating gas, and the water will follow it in the state of vapor and absorb it almost instantaneously, so that the suffocating gas will wholly disappear.

Application. Contagious vapor arising from the beds of the sick, the marsh miasmata (carburetted hydrogen combined with aqueous vapor) and other pestilential effluvia, may be neutralized as follows: Remove the sick and other persons from the room. Set a teacup or gallipot on the floor, half filled with table salt. Pour into it strong sulphuric acid, and the room will be filled with muriatic acid gas. After a few minutes open the windows, and the air of the room will be purified.

ACIDS.

Animal matter highly heated in contact with potash will yield the prussic acid, (the most active of all known poisons,) and the prussiate of potash will be formed.

Illustration. Put some shavings of hides, which may be procured at the tanners, into a crucible, and invert another crucible over it, as directed at page 100. Heat it until it becomes considerably charred; then take it out and reduce it to a coarse powder. Boil some potash in a ladle and continue the heat until the potash is reduced to a dry granulated mass. Mix the two substances in about equal parts, and heat the mixture in a ladle pretty closely covered with a sheet of iron. Raise the heat until the blaze which leaks out under the cover becomes whitish or nearly colourless. Now pour this mass into boiling water, and continue the heat some time. Skim off all carbonaceous and other substances which rise to the surface. When no more rises, stop the heat. This is the liquid prussiate of potash. It may be evaporated and form imperfect crystals.

Application. This is the most delicate test for detecting the presence of iron. But the experiment is difficult to be performed before a class, and hardly to be recommended. Prussiate of potash may be purchased of the druggists.

A solution of the prussiate of potash will form the prussiate of iron (prussian blue) *by double decomposition with a solution of sulphate of iron.*

Illustration. Dissolve some copperas in a wine glass, and an extremely small piece of prussiate of potash in another. Put a drop of the solution of prussiate of potash into the copperas, and a prussian blue precipitate will be formed.

Application. On the principle of the two last experiments, the prussian blue is manufactured in the large way. The particular manipulations are well described in Rees' Cyclopoedia. Those who are curious to become intimately acquainted with all the particulars of the process, are referred to

Mr. White at his manufactory in Rensselaer county, New-York. In him will be found the ingenuity of the artist, united to the scholar and the gentleman.

Prussiate of potash may be decomposed and prussiate of mercury formed, by boiling it with nitric oxyd of mercury, (red precipitate.)

Illustration. Pulverize some common prussian blue and put it into a florence flask. Put in about half and one eighth as much red precipitate. Then pour in about three times as much pure water (calling a pint a pound) as of the prussian blue; and boil the mixture until the red precipitate entirely disappears. This will produce the prussiate of mercury in the liquid state. It may be strained through paper, and about one fourth as much boiling water as was put in at first may be added.

Application. This salt is not much used, excepting for the purpose of procuring pure prussic acid. For this use it is best to keep it in the liquid state, as above directed to be made, closely corked up in vials.

Prussic acid may be obtained from the prussiate of mercury by heat.

Illustration. Fit a long-necked tubulated retort to a tubulated receiver. Surround the receiver with snow or ice, and set the retort into the lead pot in which the coals are but very little heated. Pour into the retort some of the liquid prussiate of mercury prepared as above, through the tubulature. Pour about one eighth part as much pure water through the tubulature into the receiver; and fit a waste pipe into the tubulature which may conduct off, into water or elsewhere out of the way, hydrogen and any other offensive gas which may arise.

In order duly to regulate the heat, &c. now put into the retort through the tubulature about half as much by weight of pure fine iron filings, as was used of the prussian blue. All being ready, now pour in as much strong sulphuric acid by weight as of the iron filings, and instantly wring in the glass stopper very tight. Blow very lightly into the air hole of the lead pot with the hand bellows, so as to raise the heat a little; but not so as to boil nor even to simmer the liquid. Hydrogen gas will pass into the receiver and out at the waste pipe. The prussic acid will come over in a state of vapor, and being condensed by the cold of the ice &c. will run down and unite with the water in the receiver. After it appears that about two thirds as much liquid is in the receiver as would equal the weight of the prussian blue (calling a pint of the liquid a pound) stop the process, cork up the prussic acid in vials and put it into a dark cellar, which is cool in summer and warm in winter.

Application. This substance is lately used in consumptive cases. Two or three drops are diluted in a large quantity of water. It is the most active narcotic known. Two or three drops on a large dog's tongue or in the corner of its eye, will kill it in one or two seconds. It is too dangerous an article to make or to use before a class. Let it be described to the class; but it should be made in the private office only. A small quantity is found in the meats of almonds, peach stones, cherry bark, the laurus cerasus, &c. And the scent of the prussic acid considerably resembles the odour of these vegetables.

Some chemists place this substance among the vegetable acids, because it is found in vegetables and not in animals. Since it is produced from animal substance I have placed it here; though I do not contend for the propriety of this location.

The basis of this acid is found by Gay Lussac to be a compound of carbon and nitrogen. It is the carburet of nitrogen by some called *cyanogen*.

Remark. The remaining vegetable acids, enumerated by authors, are of little use; and many of them are not well defined. That which is most worthy of the particular attention of the housekeeper is the

Sebacic acid. It is this acid which is so readily produced by butter or fat, giving it a disagreeable rancid flavor. Butter with this flavor is called frowey butter in New England. This acid may be neutralized by any of the alkalies. Pearlash or carbonate of soda will do it effectually. If a little pearlash be dissolved in water, and the butter be worked over with this water, all the sebacic acid will combine with the potash and form a soluble salt. If the butter is then worked over two or three times with pure water, the sebaceate of potash as well as the pearlash will be worked out, leaving the butter pure.

If cakes, &c. be shortened, in the language of cooks, with frowey butter, and pearlash be added, the sebacic acid will decompose some of the pearlash, and thereby furnish carbonic acid to assist in raising the dough. This is the best method of using rancid butter or fat. Because the alkali may sometimes be tasted after it has been applied for cleansing as before described; but when used for shortening, it cannot.

TABLES.

APOTHECARIES' WEIGHT.

20 grains 1 scruple—3 scruples 1 drachm—8 drachms 1 ounce—12 ounces 1 pound.

MARKS ON WEIGHTS.

o stands for grain—℈ for scruple—ʒ for drachm—℥ for ounce—℔ for pound—i or j for one of either, ii for two, &c.

FRENCH WEIGHTS.

A millegramme is equal to 0.154 of a grain—a centigramme, 0.1544 gr.—a decigramme, 1.5444 gr.—a gramme, 15.4440 gr.—a decagramme, 154. 4402 gr.—a hecatogramme, 1544.4023 gr.—a kilogramme, 15444.0234 gr.—a myriogramme, 154440.2344 gr.

WEIGHT OF GASES.

Atmospheric air being assumed as the standard or unity, 100 cubic inches, weighing 30 grains and 20 hundredths of a grain. Atmospheric air, 1.000—oxygen, 1.117—nitrogen, 0.968—hydrogen, 0. 074—carbonic acid gas, 1.542—ammonia, 0.596—sulphuretted hydrogen, 1.192—carburetted hydrogen, (olefiant) 0.998—coal gas, 0.450—phosphuretted hydrogen, 0.894—chlorine, 2.495—muriatic acid, 1.285—nitrous oxid (exhilarating gas) 1.527—nitric oxid, 1.043—nitrous acid, 2.135—sulphurous acid, 2.235—prussic acid (hydrocyanic) 0.946—water in vapour, 0.623—alcohol in vapour, 1.500—sulphuric ether in vapour, 2.396—spirits of turpentine in vapour, 5.013.

SIMPLE AFFINITIES.

Each substance, printed in small capitals, has the strongest affinity for the substance standing next to it, and this force is weaker for the next, and so in succession.

OXYGEN. Carbon, manganese, zinc, iron, tin, antimony, hydrogen, phosphorus, sulphur, arsenic, nitrogen, nickel, cobalt, copper, bismuth, mercury, silver, gold, platina, muriatic acid.

OXYGEN. [Set down according to the difficulty with which it is separated from metals, by heat, when combined by nature.]

Titanium, manganese, zinc, iron, tin, molybdena, cobalt, antimony, nickel, arsenic, chrome, bismuth, lead, copper, platina, mercury, silver, gold.

CARBON. Oxygen, iron, hydrogen.

NITROGEN. Oxygen, sulphur? phosphorus, hydrogen.

HYDROGEN. Chlorine, oxygen, sulphur, carbon, phosphorus, nitrogen.

SULPHUR, PHOSPHORUS? Potash, soda, iron, copper, tin, lead, silver, bismuth, antimony, mercury, arsenic, molybdena.

POTASH, SODA and AMMONIA. *Acids.* Sulphuric, nitric, muriatic, phosphoric, fluoric, oxalic, tartaric, arsenic, citric, benzoic, sulphurous, acetic, boracic, carbonic, prussic, oil, water, sulphur.

BARYTES. Sulphuric, oxalic, fluoric, phosphoric, nitric, muriatic, citric, tartaric, arsenic, benzoic, boracic, carbonic, prussic.

STRONTIAN. Sulphuric, phosphoric, oxalic, tartaric, fluoric, nitric, muriatic, carbonic.

LIME. Oxalic, sulphuric, tartaric, phosphoric, nitric, muriatic, fluoric, arsenic, citric, malic, benzoic, boracic, carbonic, prussic, sulphur, phosphorus, water, fixed oil.

MAGNESIA. Oxalic, phosphoric, sulphuric, fluoric, nitric, muriatic, tartaric, citric, benzoic, acetic, boracic, carbonic, prussic, sulphur.

ALUMINE. Sulphuric, nitric, muriatic, oxalic, fluoric, tartaric, citric, phosphoric, benzoic, acetic, boracic, carbonic, prussic.

SILEX. Fluoric, potash.

OXYD OF PLATINA, OXYD OF GOLD. Gallic, muriatic, nitric, sulphuric, arsenic, fluoric, tartaric, phosphoric, acetic, prussic, ammonia.

OXYD OF SILVER. Gallic, muriatic, oxalic, sulphuric, phosphoric, nitric, arsenic, fluoric, tartaric, citric, acetic, prussic, carbonic.

OXYD OF MERCURY. Gallic, muriatic, oxalic, arsenic, phosphoric, sulphuric, tartaric, citric, malic, nitric, fluoric, acetic, benzoic, boracic, prussic, carbonic.

OXYD OF LEAD. Gallic, sulphuric, oxalic, arsenic, tartaric, phosphoric, muriatic, nitric, fluoric, citric, malic, acetic, benzoic, boracic, prussic, carbonic, fixed oils, ammonia.

OXYD OF COPPER. Gallic, oxalic, tartaric, muriatic, sulphuric, nitric, arsenic, phosphoric, fluoric, citric, acetic, boracic, prussic, carbonic, fixed alkalies, ammonia, fixed oils.

OXYD OF ARSENIC. Gallic, muriatic, oxalic, sulphuric, nitric, tartaric, phosphoric, fluoric, citric, acetic, prussic, fixed alkalies, ammonia, fixed oils, water.

OXYD OF IRON. Gallic, oxalic, tartaric, camphoric, sulphuric, muriatic, nitric, phosphoric, arsenic, fluoric, citric, acetic, boracic, prussic, carbonic.

OXYD OF TIN. Gallic, muriatic, sulphuric, oxalic, tartaric, arsenic, phosphoric, nitric, fluoric, citric, acetic, boracic, ammonia, prussic.

OXYD OF ZINC. Gallic, oxalic, sulphuric, muriatic, nitric, tartaric, phosphoric, citric, fluoric, arsenic, acetic, boracic, prussic, carbonic, fixed alkalies, ammonia.

OXYD OF ANTIMONY. Gallic, muriatic, benzoic, oxalic, sulphuric, nitric, tartaric, phosphoric, citric, fluoric, arsenic, acetic, boracic, prussic, fixed alkalies, ammonia.

SULPHURIC ACID, PRUSSIC. Barytes, strontian, potash, soda, lime, magnesia, ammonia, alumine, metallic oxyds.

PHOSPHORIC ACID, CARBONIC. Barytes, strontian, lime, potash, soda, ammonia, magnesia, (attracts car. stronger than ammo.) alumine, metallic oxyds.

NITRIC ACID, MURIATIC. Barytes, potash, soda, strontian, lime, magnesia, ammonia, alumine, metallic oxyds.

FLUORIC ACID, BORACIC, ARSENIC. Lime, barytes, magnesia, potash, soda, ammonia alumine, silex.

ACETIC ACID, LACTIC. Barytes, potash, soda, lime, ammonia, magnesia, metallic oxyds, alumine.

OXALIC ACID, TARTARIC, CITRIC. Lime, barytes, strontian, magnesia, potash, soda, ammonia, alumine, metallic oxyds, water, alcohol.

BENZOIC ACID. White oxyd of arsenic, potash, soda, ammonia, barytes, lime, magnesia, alumine.

FIXED OILS. Lime, barytes, potash, soda, magnesia, oxyd of mercury, other metallic oxyds, alumine.

ALCOHOL. Water, ether, volatile oil, alkaline sulphurets.

SULPHURETED HYDROGEN. Barytes, potash, soda, lime, ammonia, magnesia.

PROPORTIONS OF ELEMENTARY CONSTITUENTS.

BINARY COMPOUNDS.

The oxygen 10 in all, excepting ammonia.

Water, 1.32 hydrogen—carbonic acid, 3.77 carb. —sulphuric acid, 6.66 sulphur—phosphoric acid, 8.7 phos—nitric acid, 3.51 nit—chlorine, 34.1 mur. acid—ammonia, 17.54 nit. 3.96 hyd—soda, 29.1 sodium—potash, 49.1 potassium—magnesia, 14.6 magnesium—lime, 25.46 calcium—red oxyd of iron, 23 iron—green oxyd of iron, 34.5 ir—black oxyd of copper, 40 copper—oxyd of zinc, 41 zinc —red oxyd of mercury, 125.5 merc—black oxyd of mercury, 251 merc—litharge, 129.5 lead—oxyd of silver, 135 silver.

TERNARY COMPOUNDS.

Subcarbonate of ammonia, 27.5 acid to 21.5 am---subcarbonate of soda, 27.5 carb. ac. to 39.1 soda---subcarbonate of potash, 27.5 acid to 59.1 potash---carbonate of lime, 27.54 carb. acid to 35.46 lime---carbonate of barytes, 27.5 acid to 97 barytes —sulphate of soda, 50 acid to 39.1 soda---sulphate of magnesia (dry) 50 acid to 24.6 magn---ditto crystallized, 74.6 sul. mag. to 79.3 water---sulphate of barytes, 50 acid to 97 barytes---sulphate of copper, 50 acid to 50 copper to 56.6 water---sulphate of iron, 50 acid to 34.5 iron to 79.3 water---sulphate of zinc, 50 acid to 51 zinc to 79.3 water---nitrate of potash, 67.54 acid to 59.1 potash---muriate of ammonia, 34.1 acid to 21.5 am. to 11.32 water---muriate of soda, 34.1 acid to 39.1 soda---muriate of potash, 34.1 acid to 59.1 potash---oxymuriate of potash, 93.2 mur. pot. to 60 ox---muriate of lime, 34.1 acid to 35.5 lime---muriate of barytes, 34 acid to 97 barytes ---cor. muriate of mercury, 34.1 acid to 10 ox. to 125.5 merc---submuriate of ditto, 34 acid to 10 ox. to 251 merc---sulphate of lime (dry) 50 acid to 35.5 lime---ditto crystallized, 85.5 sul. lime to 22.4 water.

EFFECTS OF HEAT AT THE DIFFERENT DEGREES OF FAHRENHEIT.

90 degrees *(below zero)* the greatest degree of artificial cold—55 nitric acid freezes—50 natural cold at Hudson's Bay—46 ether? and strong liquid ammonia freeze—39 mercury freezes—36 sulphuric acid freezes—0 cold produced by equal parts of snow and salt—25 *(above zero)* human blood freezes—30 milk freezes—32 water and oxymuriatic acid freeze—67 water boils in a vacuum—97 lard melts—98 blood heat, ether boils—107 feverish heat—122 phosphorus burns—127 tallow melts—142 beeswax melts—176 alcohol boils—212 water boils—442 tin melts—476 bismuth melts—540 arsenic is volatilized--590 sulphuric acid boils—612 lead melts—643 mercury boils—700 zinc melts—809 antimony melts—1077 iron red by daylight—1892 silver melts—2205 copper melts—2517 gold melts—6508 iron welding hot—8696 cast iron melts—10517 manganese melts—11454 soft iron melts—23177 platina melts.

ATOMIC THEORY.

RELATIVE WEIGHT OF ATOMS.

Mr. Dalton has shewn, that if the weight of the ultimate indivisible atom of oxygen be called one, the weight of the ultimate atoms of the following substances are proportioned to it as here set down. Oxygen 1—nitrogen 1.8—hydrogen 0.13—carbon 0.75—phosphorus 2.6—sulphur 2—chlorine (if simple) 4.5—potassium 5—sodium 5.88—calcium 2.6—barium 8.7—magnesium 1.5—gold 24.9—platina 12.1—silver 13.7—mercury 25—copper 8—iron 7.1—tin 14.7—lead 12.9—zinc 4—bismuth 9—atimony 11.2—arsenic 6—manganese 7.1.

NUMBER OF CONSTITUENT ATOMS IN COMPOUND SUBSTANCES.

Acids.

Water 1 ox. 1 hyd.—carbonic acid 2 ox. 1 car.—oxyd of nitrogen 1 ox. 1 nit.—nitrous acid 3 ox. 1 nit.—nitric acid 5 ox. 1 nit.—phosphoric acid 3 ox. 1 phos.---sulphurous acid 2 ox. 1 sul.—sulphuric acid 3 ox. 1 sul.—oxalic acid 3 ox. 2 carbon and hydrogen.

Alkalies.

Potash 1 potassium 1 ox.—soda 1 sodium 2 ox.—ammonia 1 nitrogen 1 hydrogen—lime 1 calcium 1 ox —magnesia 1 magnesium 1 ox.—barytes 1 bar. 1 ox.

Oxyds of metals.

Protoxyd of manganese 1 man. 1 ox.—deutoxyd of manganese 1 man. 2 ox.—tritoxyd of manganese 1 man. 3 ox.—peroxyd of manganese 1 man. 4 ox.—deut. iron 1 iron 2 ox.—per iron 1 iron 3 ox. —pro copper 1 cop. 1 ox.—per copper 1 cop. 2 ox. —deut tin 1 tin 2 ox.—tri tin 1 tin 3 ox.—per tin 1 tin 4 ox.—pro lead 1 lead 1 ox.—deut lead (red lead) 2 lead 3 ox.—per lead 1 lead 2 ox.—pro zinc (it has but one degree) 1 zinc 1 ox.

Salts.

Sulphate of soda 1 acid 2 soda---sulphate of magnesia 1 acid 1 mag.---sul. lime 1 ac. 1 lime---alum 6 sulphuric acid 5 alumine 1 potash---sulphate of copper 1 ac. 1 cop.---sulphate of iron 1 ac. 1 iron---sulphate of zinc 1 ac. 1 zinc---nitrate of potash 1 ac. 1 pot.---nitrate of silver 1 ac. 1 sil.---nitrate of mercury 1 ac. 1 mer.---carbonate of ammonia 1 ac. 1 am.---carbonate of lime 1 ac. 1 lime---carbonate of magnesia 1 ac. 1 mag.

Urets.

Sulphuret of iron (cubic) 4 sul. 1 iron---sulphuret of lead 1 sul. 1 lead—sulphuret of antimony 2 sul. 1 ant.---sulphuret of zinc 1 sul. 1 zinc---sulphuret of copper 1 sul. 1 cop.---carburetted hydrogen 1 car. 2 hyd,---sulphuretted hydrogen 1 sul. 1 hyd.---phosphuretted hydrogen 1 phos. 3 hyd.

INDEX.